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SCHOOL SCIENCE AND MATHEMATICS

FOUNDED BY C. E. LINEBARGER

A Journal for all SCIENCE AND MATHEMATICS TEACHERS

CONTENTS:

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SCHOOL SCIENCE AND MATHEMATICS

VOL. XXXI No. 9 | DECEMBER, 1931 | WHOLE No. 272

A COMPUTING CLUB.

What are you doing in your school to improve the ability of students to make simple arithmetical computations accurately? This is a neglected art in many localities. If your high school graduates can handle simple arithmetic processes with ease and accuracy they are exceptions to the general rule. Why not organize a rapid calculating club? In a few weeks they will be ready to give an assembly program that will startle the school and set the community talking. The students will have a load of fun out of it and save a full year of time after school days are over. It may prevent a failure in college mathematics or science.

ENGLISH AND SCIENCE.

No subject of study offers more interesting topics for the required themes in English composition than the sciences. Some good popular science articles for the school paper will give full opportunity for practice in sentence structure, punctuation, paragraphing and creative writing. Work up a science column. The English teachers will cooperate.

PROFESSIONAL PROGRESS.

Do you keep up your membership in professional organizations? School executives and administrators now have a large field of applicants from which to make their selections. Professional attitude counts. One individual cannot live long enough to discover all the best ways of presenting subject matter. Make use of the discoveries of others. Attend the meetings of teachers' organizations. Read professional books and journals. Keep alive.

SCIENCE IN THE ELEMENTARY SCHOOL CURRICULUM.*

By JENNIE HALL,

Supervisor of Nature Study, Minneapolis, Minn.

There is no question today regarding the need of science in the curriculum of the elementary school for both the natural environment including living things, materials, and physical forces and the man made world of "things which go" arouse in the child expressions of curiosity and wonder. Here are interests which the school must capitalize and through which not only knowledge but desirable habits, abilities, attitudes, and appreciation may be developed.

A school paper in November reported experiments made by children of the third grade who were studying foods. Louis had found his jack-o'-lantern full of cobwebs or spider webs. Discussion which followed the report informed him that "the white stuff is called mold." The question came, "How did it get there?" Experiments were planned and carried out with pieces of bread and apple. Some were placed in the dark; others in the sunlight. Some were left uncovered; other were covered. Some were exposed to dust and air; others were kept from dust and air.

Observations and conclusions such as these were made:

"No mold grew on apple and bread placed in sunlight. Sunlight keeps mold from growing.

"Apple and bread left uncovered both dried up. They didn't have water enough for mold to grow.

"Apple rubbed with dust from the top of the bookcase and covered with a jelly glass had mold on it in four days. The mold was mossy. It had little gray things sticking up."

Reports for bread were similar.

"Mold grows when food is warm, damp, and in the dark. Food that is moldy does not smell good. It is spoiled. It cannot be used again."

Several children tried these experiments at home and some experimented with other foods.

This is an illustration of satisfaction of curiosity through experimentation resulting in very valuable knowledge followed by oral and written expressions of results. Stories of the experiments were printed in the school newspaper to be used by other children as stimulating reading material.

Richard's question, 3rd grade—"Why does the moon look red and large near the horizon, and smaller and white when

*Read at the meeting of the National Council of Supervisors of Elementary Science, Detroit, Mich., Feb. 21, 1931.

it is higher in the sky?" John said that the gold fish looked larger when he looked at them through the side of the bowl than they did when he looked into the top of the bowl. A discussion followed. Then it wasn't the water that made the gold fish look large. Neither was it the glass, for in another aquarium with flat glass slides they did not look large. John thought it might be caused by the curved glass, but that did not help the original question for there wasn't any glass in the sky. More observation was necessary. Judgment was deferred until discovery of what was in the sky could be made. The next time the sun looked large and red at the horizon a thin band of clouds was discovered. When the sun emerged from this, it appeared natural in size and color. The children showed the same sort of delight that Archimedes did in his exclamation "Eureka." They too had "found it." Not one child, but many gave the answer as they entered the school room. Russell brought black goggles to school and the children experimented further to learn that through them the sun looked orange. Nor did experimentation end, for later reports told that the moon looked orange around its edge when viewed through a black sun glass.

In a second grade—Lucille brought seventeen frogs to school. Her father had found them half frozen under a boat. Lucille let one out. It jumped around on the floor.

Observations result—A frog's eyes bulge out on the sides of his head. The frog's stomach is white. The frog's back is green with black spots. His hind feet are webbed to help him swim.

Contributions of knowledge—Frogs live in marshy places or near water. They like to eat flies and bugs.

More observation and more contribution—When the frog breathes, his breast goes in and out. When he moves about, he always jumps. The frog is a good jumper because he has long, strong hind legs.

A search in books for information follows—Frogs bury themselves in the mud and sleep for the winter. In the spring they lay their eggs. Later the eggs hatch into polliwogs. These polliwogs have long tails. As the polliwogs grow into frogs their tails gradually disappear. It takes about six weeks for some polliwogs to grow into frogs.

More contributions—Men use frogs for bait. Frogs' legs are good to eat.

Nature minded Lucille had also contributed to her room a baby mouse with a broken leg, a big frog, six baby clams, and a baby sunfish. According to records the sunfish gained one inch in length in the school aquarium from September until November 12.

Contagion spread, for Robert made contributions of snails and snapping turtles and Joan brought a turtle shell, Harry and Wilbur clam shells, and Jean a large shell which grandmother had used for a dinner horn. Harry and Peter contributed twigs of pine trees, Billy a piece of pine wood, and Robert petrified wood from the Black Hills. Dorothy presented a stone weighing three pounds which she had brought from Lake Superior, Suzanne a transparent stone and some mica, Joe some marble, and Billy's uncle furnished pieces of red, black, and gray marble. John's grandfather had been to Iceland and so John displayed a piece of lava which had come from there. Interest was dominant. Language expression was natural. Readers and other books were searched for information, pictures were collected, and drawings of various kinds were made for illustration of the nature language stories.

Nor was the friendly cooperative spirit of learning through doing confined to one room. A neighboring second grade had had a delightful experience with excursions which resulted in a study of fruits and seeds. The children enthusiastically exchanged their results.

In a sixth grade a group of boys found a saprophytic fungus growing on a tree near their school. Curiosity was aroused. In an attempt to procure the specimen which was some twelve feet from the ground, the discovery was made that the bark of the tree was loose and easily peeled off. Insects' tracks were numerous in the loosened bark. Curiosity increased. Neighboring trees were discovered to be in similar condition. Interest was awakened. Judgments were made and questions raised. "It must be a disease. Had it spread to the park trees across the street and to the trees of the school lawn across the street in another direction?" Alarm was spread. Appeal was made to a sympathetic teacher. Books were searched and illustrations were

gathered. The librarian was interviewed. The supervisor of Nature study was called for assistance. Interest in fungi and their habits controlled the school day for a time. Information was given to the Park Board and help was immediately offered in response. The Park Board horticulturist diagnosed the difficulty, the tree surgeons trimmed and treated the school and park trees. The gas company cut the offending trees because leaking gas had slowly devitalized them. An informational program was given to the mothers' club. A committee visited the secretary of the neighborhood commercial club to interest him in conservation of the neighborhood trees.

Children of another school who learned of the project requested that the boys and girls tell them all about fungi. A profitable, happy and natural auditorium program resulted.

What were the outcomes? Many of them are immeasurable. There was much knowledge gained; there were numerous language and reading results. Interest in school, in the out-of-doors, in science, in conservation, in city organizations, and in the community were established. Much opportunity was given for development of the ability to cooperate. Appreciation for property rights grew and some appreciation of the interdependence of all life was developed.

The teacher wrote:

"I feel that this work was the making of this particular class. They had been considered rather slow mentally, troublesome in discipline, and wanting in interest, wasters of time, and not dependable. The situation has become almost the reverse. Today they are happy, cooperative, interested, and interesting children. They are ready to try anything. They do much reference work. No effort is too great for what they wish to find out."

Enough time must be given to the study of the child's contribution to whet his interest. His questions and specimens may be received during the opening exercises. Children in their response will easily dispose of uninteresting material and will also guide the group to interests of their own level. Since expression accompanies vital interests of children, the science experiences result in the best type of language work, both oral and written. Such interests will just as surely lead to reading for information and for entertainment.

However, in order to assure desirable outcomes, definite

science subject material must be developed for each grade level. The trend of curriculum organization in elementary education is toward the integration of related subject material into large units of study. Science by its nature is a part of many such units.

Units in farming in the first grade in Minneapolis have included a study of domestic animals, of pastures, grain fields, gardens, of machinery such as windmills, plows, harrows, harvesters, gas engines, milking machines, feeding machines, pumps, electric generators, water plants, etc., of storehouses for feed and bedding such as silos, corn cribs, hay lofts, and straw stacks. To be sure, this does not mean an exhaustive study has been carried on by these little people, but an excursion to any modern farm exposes the child to a great variety of science subject material. He sees much. His learning is not complete until the questions which his active mind raises are satisfactorily answered for him.

In the same way units in transportation in the second grade have led children into the study of animals used, as, beasts of burden, to other forms of power, steam, gas, electricity, to fuels, coal, oil, wood, etc., to mechanics of wheels and axles, harnesses, and engines, to lights used as signals and for illumination, to physics of floating on water and in air, to land vehicles of all kinds, and to various types of boats and aeroplanes.

In the third grade a study of food takes the child to production in gardens and on farms, to preparation and to manufacture, to preservation, packing and transportation, and to development of new foods.

All of these are basically scientific problems, mastered by men as a result of scientific study and experimentation.

In the intermediate grades coincident with the development of units in the social studies, geography, and history, the child must be introduced to the basic scientific facts of the earth's rotundity, to man's method of location of positions upon the earth, and to his division of time. He must also become acquainted with the fundamental principles of climatic causes and weather phenomena, of surface conditions and changes, and of movements of the waters of the earth. He must be given an acquaintance with the laws

of growth and development of plants and animals, and he must know something of the natural resources and physical laws. Such knowledge is fundamental to the understanding of both geography and history because men have learned slowly through the ages to live in the various types of climate and upon the various kinds of land, and because men have learned slowly through the ages to use and to modify for use natural materials and living plants and animals.

These facts and principles have always been included in the study of geography and history, but without learning experiences they are readily memorized by pupils and used with little meaning. They can and should be scientifically developed at the proper levels.

Through measurement and records of the daily and seasonal length of a child's shadow, through shadow games, and through observations and records of shortening days, kindergarten and primary children may easily be led to appreciate that seasonal changes are dependent upon the sun. Almanacs, calendars, and daily papers offer source material.

The radio has aroused questions regarding difference in time. A sundial made by a group of sixth grade children and set in their school garden stimulated interest in finding time throughout the building even to the kindergarten where a child pointed to the shadow and said that it "told the time by the sun." In a sixth grade the report that a California school had a sun dial hanging on the south wall of their building was the cause of an attempt to do the same. These children were puzzled to discover that when their shadow board was hung vertically the gnomen shadows were long when the sun was high in the sky and shorter when the sun was low. The reverse had been true on their horizontal shadow board. Records were repeated until they were certain that their results were correct and that the shadow story of the movements of the sun was the same. A fourth grade used a flash light to prove that direct rays cover less space than slant rays, and that therefore the more direct the ray of sunlight the greater is the heat.

Even climate and weather become both interesting and instructive to primary children when records of observa-

tions are kept and monthly summaries, comparisons, and judgments are made.

Observations of phenomena of weather, snowstorms, rainbows and raindrops, dew, frost, cloud, and fog, and experiments in freezing and evaporation of water, and melting of ice are fascinating to primary children. Through them a rich background of experience is gained which may be constantly drawn upon in the upper grades.

The weather report and prophecies and the weather bureau offer interesting fields of study for the intermediate child, especially since the aeroplane has made people more weather minded.

In the same way observations of the work of running water on hillsides and in gutters during melting of ice and snows and after heavy rains aid the children in understanding the forms of land and water as well as the principles of erosion and deposition.

Resourceful teachers, interested children, and watchful principals and supervisors altogether can and must produce suggestive and helpful learning experiences for these basic scientific facts and principles.

The problems of subject material and grade placement are numerous because their solution is dependent upon so many factors such as:

a. the particular environment
b. children's interests
c. specific units and subjects of the curriculum

Because environment of schools varies so greatly and because interests of children are distributed in so many fields, a grade outline might include two types of activities,—one consisting of learning experiences which are possible to all environments and all children and which develop the essential basic facts and principles necessary for the understanding of the social studies, the other consisting of a suggested list of learning experiences which are dependent upon the environment and which satisfy the interests of children at that particular level. For example, in Minneapolis some knowledge of insect pests is desirable for the social studies program in the fifth grade. It may not be possible for a class to procure specimens for study of any specific plant pest, but it is possible for every class to observe the complete life history of some insect, and there-

fore to be able through reading and illustrations to understand the activities of any insect.

Another question arises; is the regular classroom teacher of the elementary school prepared for science teaching? The results of several studies of teacher training schools show that preparation in science is quite inadequate. On the other hand, in science learning experiences the teacher is a participator and can readily learn with the child. It has been my pleasure to see many teachers become enthusiastic seekers of science knowledge because of interests aroused by classroom activities. The teacher who has much technical training, but who has had little experience in seeing children grow in knowledge through observation and experimentation often gets poorer results than a good teacher of children who is untrained in science. The one tells too much whereas the other who cannot tell because she does not know becomes a thoughtful suggestor and learner. The children's interests, problems, and results are common to her. Their joy and satisfaction in outcomes are no greater than hers.

This statement does not imply that science training is unnecessary; it does mean that desirable attitudes and understanding of learning habits are quite as necessary for the teacher as knowledge of science itself.

Excellent science work can be done in the elementary grades with little equipment. A sunny window with growing pans, some sand, black soil, commercial fertilizers, flower pots, a few glass receptacles, and possibly a small garden plot is all the equipment necessary for numerous experiences in growing plants. Inexpensive aquaria, terraria, and pet cages will house living animals for observation. Electric wire, magnets, dry cells, rubber tubing, a few glass receptacles of varying sizes, gas and electric connections will allow numerous simple experiments in physical science. Cabinets or cases in which children may assemble their own museum specimens are a source of delight. A vacant room which may become a workroom stimulates the development of interesting projects.

The concomitants of science are great for it offers an opportunity for development of many desirable habits, interests, abilities, and appreciations.

The habits of scientific thinking are direct outcomes of science activities because the learning experience follows a vital question and requires observation and experimentation to discover the data for conclusion. Because many of these experiences require time for fulfillment, records must be made and judgment must be deferred.

Some kindergarten children set twelve eggs under a hen and faithfully recorded in illustrated story form the activities of Henny Penny, the mother, and of the broad of chicks.

So changed was the appearance of the young chicks when the children returned to school in the fall that absolute evidence of their identity was required of the committee of older children who had attended to the needs of the family during the summer vacation. The children insisted that they had been little and now they were large and much like Henny Penny. The fall months slipped by with little interest, but with winter came a new surprise. "A big little chicken had laid an egg." It had become a hen.

Anxiously spring was awaited when weather would permit the placing of eggs under the pullet. Would she brood them as her mother, Henny Penny, had done?

The ability to conclude from data is a natural consequence of the habits of scientific thinking. The child who is taught to recognize the relationship between cause and effect and who learns to establish proof for his statements is more likely to use judgment when making decisions in life than is the child who has had no such training.

Frequent exposure to the phenomena of nature and to the operation of man-made tools and conveniences stimulates the child to observe and to question.

The continued satisfaction of childish interests in the living world and in the physical and mechanical environment, tends to the development of broad interests in nature and science. These add greatly to the personal resources and therefore to the enjoyment of life.

Such a program of science as has been outlined leads even the primary child to books, first for information and next for enjoyment. The habit of constantly seeking information, verification, and pleasure from books develops a decided interest in reading. This broadens the horizon and consequently the satisfaction in living.

The desirable attitude of cooperation is engendered when children actively experiment and work together to solve their problems.

Some appreciation of the wonderful and beautiful in nature and of the marvelous developments in science results from a definitely planned and well organized and conducted course in science. Such appreciations help in the interpretation of literature, music, and other forms of art, and deepen the enjoyment of life.

ANALYSIS OF ERRORS AND DIFFICULTIES OF BEGINNING TEACHERS IN GENERAL SCIENCE.

By EDITH M. SELBERG, *Colorado State Teachers College, Greeley, Colo.*

ERRORS IN SCHOOLROOM MECHANICS

Failure to regulate light and ventilation.
Failure to use time saving devises in distributing materials.
Does not provide time to put away materials.
Fails to have proper equipment ready for use.
Disregard his own posture.
Lack of order in passing from room to room.
Fails to quiet pupils upon entering the room.

ERRORS IN RECITATION AND DIRECTED STUDY.

Too much teacher activity.
Fails to apply the scientific principles to a practical situation.
Fails to drill on scientific words and phrases.
Assignments inadequate due to incompleteness and indefiniteness.
Directions poorly given.
Answers questions that pupils can answer.
Questions not worded clearly and concisely.
Questions do not focus upon the principles of the unit.
Failure to emphasize the elements of problem solving.
Students not made to evaluate own statements.
Does not insist upon reasonably good English.
Pupil's voice audible to teacher only.
Teacher's voice indistinct.
Lack of illustrations to clarify principles.
Fails to see that Language is confusing to the class.
Fails to ask questions which require reflective thinking.
Fails to use blackboard to good advantage.
Fails to provide supplementary material.
Fails to locate pupil errors in solving problems.
Fails to stimulate disinterested student.
Fails to provide for individual differences.
Fails to guide pupils in the analysis of problems.

ERRORS IN TESTING.

Fails to select important concepts for testing.
Fails to test for the elements of problem solving.
Statements ambiguous.

MAJOR PROBLEMS IN THE TEACHING OF NATURAL SCIENCE.*

By ERNEST E. BAYLES,
University of Kansas.

In his much discussed Inglis Lecture in Secondary Education for 1930, Dr. Thomas H. Briggs makes this statement: "School people are limited in competence, not so much in the details of their jobs, as in a large comprehension of their significance. In other words, like the lay public, they need more than anything else an understanding of what education is for, of the ends that it is supported to achieve."

It appears to your present speaker that we, as science teachers, can very well afford to take to heart this statement of Professor Briggs, and, before we go further along the line of revision and adjustment, take thought as to what we are about and whether or not we are really accomplishing what we want to accomplish.

When one stops to think on the matter for a moment, there would seem to be little objection that could be raised against the statement that, in order to decide upon the policy that should be adopted in any phase of teaching, it is first necessary to decide what it is that we expect the teaching to accomplish. Otherwise, we are likely to be led this way and that by the passing fads and fancies of the hour. At the present time we are in the grip of the unit, and everything we pick up is given the unit label. Our new textbooks and workbooks in general science would probably not sell at all were the various divisions called chapters instead of units. Not long ago our courses were divided into projects and problems. I am wondering what the next shibboleth will be.

Now I have no particular objection to the use of new terms. Variety is the spice of life, you know, and new terms are often the accompaniment of new ideas. But I am concerned as to whether or not each new step that we take is a forward step and is not one which comes down in the same place as the one before, merely marking time. I therefore repeat that, in order to develop a proper teaching procedure, it is necessary to decide first

*This paper was read before the Department of Science Instruction of the N. E. A., at Los Angeles, Calif., on Monday afternoon, June 29, 1931.

what it is that we expect the teaching to accomplish.

Surprisingly enough, while this tenet sounds reasonable, we find that it has not been followed with any degree of consistency. A committee, headed by Persing, made a number of studies of the sciences in Cleveland in 1925, in which they asked teachers to set down their teaching aims. Then, in order to see how nearly these aims were lived up to, the committee subjected the student examination papers of these same teachers to scrutiny. The conclusion from this phase of the investigation was that there appeared to be small relationship between stated aims and the results that were actually sought in the instruction. Another study, coming also out of Cleveland, was made by Muthersbaugh on objectives in physics. In this case the investigator examined a number of recent courses and syllabi, and reached the rather startling conclusion that only one of the half dozen or so which were examined made any systematic attempt to follow out the objectives that were laid down for the course. Powers, after making a study of the claims for chemistry in textbooks, syllabi, and published articles, and listing the objectives found, states that the list "illustrates the failure on the part of those responsible for instruction in chemistry to recognize in their statements, objectives that are sufficiently specific to suggest subject-matter and class room activities which would be useful for their accomplishment."

The difficulty is that we set down long lists of things that we feel we should accomplish, and then file the lists away and forget about them. We make the lists long so that they will make a sufficiently impressive appearance. We file them away so that we can find and exhibit them when someone asks what we are trying to do.

It seems to me that we should make an attempt to get down to brass tacks on this matter of objectives, and then fasten our thinking down to fundamentals by the use of these tacks after they have been discovered. In order to build up divisions of subject-matter which are of suitable size for class room use, which will require the type of activity on the part of the student that is really conducive to learning, and which will develop in the student the outcomes which are useful and relatively permanent,

it would seem that we must ask ourselves what is, after all, the real purpose of the knowledge that is embodied in our particular field. The question, therefore, resolves itself into what is the real purpose of science.

To answer this question let us go first to the pure scientist. We will find him gathering facts and figures, data which he will carefully scan and analyze until they reveal certain essential, underlying relationships which are explanatory, and which can, therefore, be used in the prediction of new behavior. The true scientist is not satisfied merely to find out facts as they are; he is interested in finding out what these facts mean. The meaning clear, he is then ready to give to the world a tool for prediction. The applied scientist takes the predictive tool—this statement of relationship—and proceeds to make practical use of it in the control of the forces of nature. Illustrations lie around us everywhere, and I believe it unnecessary to enlarge upon the proposition. Suffice it to say that it would seem that one is entirely justified in saying that the essential function and purpose of any scientific classification of knowledge is the prediction, and subsequent control, of the behavior of one's physical or biological environment that is thereby made possible.

Since such is the end and purpose of science, it logically follows that such should be the purpose of classroom instruction in the sciences. The purpose of the school, as has often been stated, is "to teach the child to do better those things which he is going to have to do anyway." We can well change this statement to fit our particular subjects by saying that the purpose of the class in science is to teach the child to do intelligently and understandingly certain of the things which he is going to have to do anyway. As the result of instruction in general science, he will, we hope, not only demand a good water supply system, but he will know why he is demanding it and will be pretty well able to judge for himself when he has obtained such a system and when he has not.

In order to develop this predictive ability on the part of our pupils, it is necessary that the objectives of instruction be something more than the mere accumulation of, and ability to recall, facts. The scientist, in seeking new predictive devices, must do a good deal more than merely

gather facts. There are many who gather facts, but there are only a few who mould facts into predictive devices. The latter only are the ones which we call scientists. In the schoolroom, almost anyone can ask questions with a book lying open before him, but it is only the true teacher who gets the student to use facts in such a way as to make them over into guides for thinking. In the hands of the real teacher, facts become means to an end, and are not the end in themselves. They are illustrative, giving concrete, tangible examples which show how a given relationship or principle will work out. The generalized relationship—the principle—is the real end of the instruction. Just as the scientist has to arrive at a generalized statement of the relationships shown by his facts before he can give to the world a predictive tool, so must the student arrive at an understanding or comprehension of the relationships which are illustrated by the material presented to him before he can make the material useful to himself.

It is only through the understanding of principles (generalized facts) that the student can make use of his knowledge in solving the new problems that are continually arising in his experience. Knowledge is bookish and impractical to the degree that the learner attempts merely to remember it in its original form. If the knowledge presented to him is interpreted and seen (understood) in terms of the principles which it illustrates, it becomes usable knowledge since comprehended principles can be applied in the solution of new problems and can be used under constantly changing conditions.

Since, in order to make use of scientific knowledge, it is necessary to teach it in the form of principles, it most assuredly follows that every step in the teacher's method must be planned with that end in view. The first problem is that of the organization of subject matter. We must have courses that are organized around the various principles fundamental to the science. This is a basic requirement, and it will make necessary some pretty radical changes in the outlines of the courses which we offer. Biology, chemistry, and physics are certainly not now organized on the basis of principles, although physics comes closer to it than either of the other two. We find such

titles in biology as "Seeds," "Flowers," "The Grasshopper," "The Frog," "Mammals," and "Flowering Plants." These titles are purely descriptive, and imply chapters which are descriptive only. Science must do something more than merely describe. It must organize and interpret.

Organization of courses with the end in view of establishing comprehensions is sure to be conducive to hard sledding for many traditional high school courses. Witness the change which is wrought by the following twelve titles which represent considerably more work than the average tenth grade biology student can comfortably accomplish in nine months:

The Nature of Living Things.
How Living Things Are Adapted to Their Environment.
How Plants Are Adapted for the Manufacture of Food.
How Food is Prepared for Use in the Bodies of Living Things.
How Food is Used in the Bodies of Living Things.
The Conservation of Our Biologic Wealth.
Modification and Improvement of Plant and Animal Forms.
How Living Things Maintain Their Kind.
How Living Things Maintain Health.
The Control of Plant and Animal Behavior.
How Plants and Animals are Distributed Geographically.
How Our Knowledge of Biology has Developed.

Or consider the following ten units which will keep a high school chemistry student hustling for thirty-six weeks:

How Chemical Changes may be Recognized.
How to Distinguish Between Solutions and Suspensions.
What the Chemical Formula Represents.
How Chemical Changes are Represented.
How Ionic Substances Act in Solution.
The Metallic and Non-metallic Nature of the Elements.
The Nature of Chemical Action Involving Oxidation and Reduction.
The Place of the Carbon Compounds in Natural and Industrial Processes.
The Place of the Nitrogen Compounds in Natural and Industrial Processes.
The Periodic Classification of the Elements.

Or think over the following eleven titles which constitute a rather careful revision of the course in high school physics:

How Work is Accomplished.
How Man Makes Use of Gaseous and Liquid Pressures.
Why Objects Float.
How Man Controls and Utilizes Energy in the Form of Heat.
Sound Production and Control.
How Latent Energy is Converted into Useful Work by Heat Engines.
Magnetism and Electromagnetic Induction.

Heating and Lighting by Electricity.
The Chemical Effects of the Electric Current.
How Light is Controlled for Securing Effective Vision.
How Bodies are Affected by the Forces which Act Upon Them.

These titles are suggestive only, and do not in all cases give a complete picture of the principles which they serve to introduce, but they represent the fruit of several years of thoughtful formulation and of careful tryouts in the classroom, and illustrate, I believe, the direction of development that we may expect our courses to take within the next few years.

The clear definition of objectives, and the subsequent reorganization of courses that is forced upon us, lead us immediately into another problem—that of testing or measurement. If we are to be consistent—and not to be consistent causes us to fail signally in putting student achievement over—the outcomes of instruction must be measured in terms of the objectives which we set out to achieve. If we seek the development of comprehensions, we must, therefore, devise tests which will measure the presence of comprehensions. Such tests, like the reorganized course outlines, are decidedly different from the tests that we have been giving our students. Studies made within the past five or six years give us the information that science teachers' examinations are between 85 and 90 percent fact recall. A fact recall test does not measure comprehension. A fact recall test requires that the student reproduce the learning material in the same form in which it was presented to him. It calls for reproduction only. A comprehension test, on the other hand, requires that the student deal with problems that are new—situations with which he has not come into contact before. Psychologists tell us that one of the essential criteria for insight or comprehension is the ability of the individual to think through to the correct solution of novel situations which involve the comprehension. The mathematics or physics teacher gives his students new problems, the solutions of which depend upon the use of ideas that have been included in previous instruction. We are all familiar with this type of examination in connection with numerical problems, and would think it absurd if any other type were used. In just the same way should the teacher of biology, physics, chemistry, or any other sci-

ence test out the achievement of his students. The only difference is that non-numerical problems should be used instead of those which are numerical. While the fact recall test calls for *reproduction,* the comprehension test demands *reorganization* of experience.

I have been able merely to introduce the problem of testing for comprehension. There is no opportunity for even the introduction regarding arrangement of classroom activities, because there is another consideration that must be brought up during this discussion.

The question will be raised, "What are you going to do about the attitudes and the skills that are supposed to be developed by science instruction?" We will be asked if we are not forgetting entirely the things that really amount to most in the course of a full and complete education. The answer is emphatically and unqualifiedly, "No! We are not forgetting the attitudes at all. We are just beginning to make their attainment possible." Witness the "get-by" attitude of our students today. Whose fault is it that this attitude exists? It is the fault of the system that makes it possible that a student slide through his courses without being asked to show real accomplishment. So long as we don't know what we are after, how can we know when it is accomplished? So long as we don't know when it is accomplished, how can we measure progress? The student is moved from one level to the next on the basis of time spent and not on the basis of goals achieved. Measurement of achievement made with valid measuring tools, measurement in terms of the stated objectives of a course, is going to go far toward a correction of this defect in the product of our educational system.

The crux of the matter is that the most potent factor in the establishment of a proper attitude toward one's environment is the understanding of that environment. You will make little headway by exhorting an individual to drop his superstitions, but if you lead him to a clear realization of the real causes of the phenomena in question you will have entirely undermined the old attitude. You may talk yourself blue in the face about scientific attitudes, but you won't get half so far in the end as you will by putting over in the mind of your pupil a few scien-

tific concepts and letting him get the personal thrill that comes from the successful utilization of those concepts in the solution of puzzling problems. Teaching children attitudes without teaching the understandings which must serve as the basis for these attitudes is pure propaganda, and should not be tolerated in public schools. Give the student first a clear realization of the way the various factors of his environment function, and you can be pretty well assured that the attitudes will take care of themselves. Try to establish desirable attitudes by direct methods, and often all is lost.

And so, to summarize, I would say that teachers of the sciences must do some clear thinking in regard to what they expect to accomplish in their classrooms. Then, when this is done, they must never lose sight of these objectives. Since the prediction and control of behavior is the essential aim of the scientist, it should also be that of instruction in the sciences. This aim requires the teaching of principles instead of facts, and of establishing the ability to apply instead of the ability to reproduce. A program of course reorganization, effective classroom management, and valid measurement of results, all in terms of this end, will, by the same gesture, lead to the accomplishment of those other ends which are so necessary to a complete education.

UNITED STATES CIVIL SERVICE EXAMINATION.

The United States Civil Service Commission announces the following-named open competitive examination:

School Social Worker (Visiting Teacher)

Applications for the position of school social worker (visiting teacher) must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than December 30, 1931, except that the Commission reserves the right to issue subsequent notice closing the receipt of applications before that date.

The examination is to fill vacancies in the Indian Service.

The entrance salary is $2,300 a year.

Competitors will not be required to report for examination at any place, but will be rated on their education, experience, and fitness.

Certain specified education and experience are required.

Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post office or customhouse in any city or from the United States Civil Service Commission, Washington, D. C.

MATHEMATICS IN THE SCHEME OF GENERAL EDUCATION.

By J. S. GEORGES,

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The present paper is the first of a series of articles constituting a report of a study conducted at the University of Chicago. The study was undertaken in 1926, at the suggestion of Professor H. C. Morrison, and was completed in 1930. The author is indebted to him for his help in the accumulation of data, for his suggestions and criticisms in the analysis and presentation of results, and for his interest in the study and his desire to present the findings to the teachers of mathematics through the publication of these papers.

The seven articles will deal specifically with the following reports:

1. The statement of the problem, and a discussion of its significance.
2. A description of the method used in collecting and classifying the data preparatory to their analysis.
3. The analysis and interpretation of the data in terms of the elements of the problem.
4. The presentation of the findings in terms of definite units for mathematical instruction.
5. The organization of a selected unit for the purpose of instruction.
6. A description of the methods and modes of instruction used in the teaching of the unit.
7. The evaluation of the results of instruction.

Introductory to the formulation of our problem it is necessary first to give a brief discussion of the field for study, which is, so to speak, a field within a field; the field of mathematics contained within the larger field of general education. We focus our attention to the specific characteristics of the field of mathematics and endeavor to interpret them in their relations to those of the field of general education. Broadly stated then our problem is: the determination of the unique function of mathematics in the scheme of general education.

The term "general education" is used here to discriminate between education and specialization. We are not attempting to find out the kind of mathematics a specialist, such as a physicist, a chemist, or an economist, needs for the

comprehension, representation, and interpretation of the problems and phenomena in his specified field. On the other hand, the problem is concerned with the determination of the mathematical concepts, processes, and principles which are needed by an educated person, and which are useful to him in living the life of an educated individual. The specific formulation of the problem will be based upon this unique relation between education and mathematics.

The interest and concern in the educative functions of mathematics, directly or indirectly, has received attention wherever systematic educational methods and policies have been adopted. Historically there has been an intimate relation between mathematical education and general education. For the most part the teachers and the educated of the early civilizations were either trained mathematicians or had a mathematical education, as adequate as their times could afford. There were times when the ability to read, to write, and to use mathematical processes stamped a person as being educated. And so centuries later, "Reading, Writing, and Arithmetic" were still considered as the necessary prerequisites of an adequate education.

However, because of its immediate bearing we are inclined to consider the problem as of recent times, and to magnify its importance and its complexity. A subject which occupies so much of the school-time of the individual should naturally be subjected to the scrutiny of the educators, the teachers, and the general public as to whether the investments of time, money, and effort in the subject yield fair returns. Consequently the problem of the functions or values of mathematics in the educative process has received considerable emphasis in the educational literature of the past few decades.

A survey of the available literature discloses the fact that the discussions of the problem and contributions to the formulation and study of the problem have come from three distinct sources. They are: (1) the professional educators; (2) the professional mathematicians; (3) the teachers of mathematics in the elementary school, the secondary school, and the college.

The contributions of the professional educator have been of two types: (1) criticisms; (2) statistical studies.

The contributions of the professional mathematician have

been: (1) counter-attacks; (2) defensive arguments; (3) philosophical discussions.

The contributions of the teacher of mathematics have been: (1) subjective discussions; (2) experimentations; (3) inquiries; (4) criticisms.

But what of the educated person, what has been his attitude in the controversy concerning the values of mathematical education? The answer to this question has been the sole reason for the undertaking of our study, and the guiding principle in leading us out of the apparent confusion of ideas.

The perusal of the above literature has convinced us of one significant fact, and that is that the real issue, which has been the basis of the voluminous discussions, has not been clearly stated. The issue is this: Are the mathematical concepts, principles, and processes, which are selected for instructional purposes, the aims of such instruction, or are they the means of attaining certain other ends which constitute the genuine aims of mathematical education?

In his criticisms the professional educator has assumed that an abstract science cannot be of much practical importance in the affairs of human life. The more familiar criticisms of mathematics have denied the traditional claims as to its values, and have constantly insisted that its contents be judged mainly on the basis of their utility. The argument for utility has profited by the increasing public interest in vocational education.

This assumption is further strengthened by the fact that in the teaching of the subject the practical and experiential background which is the basis for most of the mathematical abstractions is often lost in the development of the theoretical considerations. These considerations employ abstract ideas in the development of a science which takes the particular relationships discovered through perception and senses and generalizes them into conceptual laws. It is true that the abstract ideas employed, or their manipulations, may not have direct practical value to the average person, nevertheles, the relationships and laws which these abstract ideas represent are the very life of our present civilization and cannot be said to be of no consequence to the educated man or woman.

The second factor contributing to the confusion and mis-

understanding regarding the true significance of mathematical instruction arises from the habit of attributing the shortcomings of the teaching of the subject to the failure of the subject itself to measure up to the educational values commonly claimed for it. Such criticisms of the methods of instruction are justifiable and useful for they have pointed out objectively the shortcomings in the realization of the aims and functions of mathematical instruction and have, in a measure, paved the way for a reorganization of the instructional materials, and for the improvement of instructional methods. However, methods of instruction must not be confused with the evaluation of the intrinsic and unique functions of mathematics in the educative process.

The third factor contributing to a misapprehension of the true functions of mathematical instruction is a result of inadequate and one-sided analyses of the values of mathematics in specified activities. Educational investigators as a whole are not primarily mathematicians, many of them have not had an adequate training in mathematics, consequently their findings have lacked reliability because of a lack of proper interpretation of the significant concepts and processes of mathematics. The analyses have revealed only the obvious quantities, operations, and processes without penetrating deeper and apprehending the relationships and laws in the interpretation of which these operations and processes are utilized.

However, the most serious objection to the results of educational investigations which have endeavored to discover the functions of mathematical instruction is the failure of the investigator to find out what mathematical processes and concepts might be used to advantage if they were in the possession of both the author and the reader. That the average educated person is ignorant of the basic concepts of mathematics is a fact reluctantly admitted, and unconsciously these investigations have affirmed this belief. Consider, for example, the following "scientific investigation" and the conclusions of the investigator. In commenting on a study, which was intended to disclose the nature and amount of mathematics needed in Freshman chemistry, the findings are summarized thus by a noted educator: "The mathematical information needed in Fresh-

man chemistry is limited to arithmetical operations and simple algebraic processes with a wide range of denominate numbers." Tables of frequencies are given for denominate numbers, arithmetical fractions, algebraic addition, equations of the first degree in one and in two variables. But nothing is said, for obviously nothing was seen, of such important and basic principles which are the very essence of a scientific attitude, be it in the field of chemistry, physics, or any other specified field, such as: representation, variation, invariance, functionality, transformations, and mathematical laws.

It is thus apparent that any investigation which has for its purpose the analysis of specified activities for the determination of the instructional aims of a given subject in those activities will yield only what the investigator is able to identify as activities, directly or indirectly, associated with the subject. That is of two investigators employing the same methods in the solution of the same problem, the one who is better trained in the subject matter will invariably interpret the unique and intrinsic functions of his subject more adequately. What this training of the investigator in the subject matter should be is a matter of personal opinion. However, in the case of mathematics we may reasonably expect that no person is adequately trained to interpret the intrinsic values and functions of mathematics in general education, or in even a special field of education, who has not had the equivalent of a master's degree in the subject.

However, the problem is more complex than the statement of the academic preparation of the person engaged in its solution. Further discussion of its complexity must be in terms of three groups of individuals who are directly or indirectly associated with it: The educator, who, as we have already seen, is not qualified to present a complete solution. The teacher of mathematics, who is vitally concerned with an adequate solution, and who is in a better position to carry on the necessary studies toward the solution of the problem, has been influenced on the one hand by the professional educator, and on the other hand by the professional mathematician. And finally the professional mathematician, who when driven to the task is ready to defend the benign influence of the Muse of Mathematics, but complacently trusting in the efficacy of mathematical

knowledge is oblivious of the mathematical needs of the average educated person.

To the critics of the intrinsic values of mathematics, the mathematician has replied that the concepts, doctrines, principles, and processes of mathematics are the embodiments of standards and prototypes of all life activities. He is somewhat irritated by the failure of the critic to see the applications of mathematics in manifold activities. And his answers to the criticisms against the educational values of mathematics have taken the following forms.

The question of the relations of mathematics to the scientific method is thus answered by Sylvester. "Mathematical analysis is constantly invoking the aid of new principles, new ideas, new methods, not capable of being defined by any form of words, but springing direct from the inherent powers and activities of the human mind, and from continually renewed introspection of that inner world of thought of which the phenomena are as varied and require as close attention to discern as those of the outer physical world. . . . It is increasingly calling forth the faculties of observation and of comparison. . . . It has frequent recourse to experimental trial and verification, and it affords a boundless scope for the exercise of the highest efforts of the imagination and invention."

To the question: What are the relations of mathematics to art, music, and esthetic appreciations? Poincaré answers: "Those skilled in mathematics find in it pleasures akin to those which painting and music give. They admire the delicate harmony of numbers and forms; they marvel when a new discovery opens an unexpected perspective; and is this pleasure not esthetic, even though the senses have no part in it?" And Thomas Hill answers: "Mathematics and poetry are utterances of the same power of imagination, only the one is addressed to the head, the other, to the heart. Poetry is a creation, a making, a fiction, and mathematics, the sublimest and the most stupendous of fictions."

To the question: What are the relations of mathematics to the historical records of the race? Miller answers: "Just as the stars speak with increasing clearness and effectiveness to the growing astronomer, or as the plants have added interest to the advanced botanist, so does mathematical history convert the narrow mathematical logician into a man

who sees in his symbols, in his theorems, and in his methods, useful guide posts to the intellectual history of the race. The dignity of the human mind stands forth more clearly when viewed from these heights of permanent triumphs, and the various falterings and shortcomings in advancing toward simplicity and generality in mathematical results tend to cultivate a true attitude of mind toward the various intellectual weaknesses so noticeable in our surroundings."

To the question: What are the relations of mathematics to language and to methods of expression? Whitehead answers: "Algebra is the intellectual instrument which has been created for rendering clear the quantitative aspects of the world. . . . To talk sense is to talk in quantities. . . . You cannot evade quantity. You may fly to poetry and to music, and quantity and number will face you in your rhythms and in your octaves. Elegant intellects which despise the theory of quantity are but half developed. They are more to be pitied than blamed."

To the question: What are the relations of mathematics to philosophy? Keyser answers: "The domain of mathematics is the sole domain of certainty. There and there alone prevail the standards by which every hypothesis respecting the external universe and all observations and experiment must finally be judged. It is the realm to which all speculation and all thought must repair for chastening and sanitation, the court of last resort for all intellectual whatsoever. . . ."

But these citations, and others that we might add, presenting the opinions of expert mathematicians bearing upon the relations of mathematical facts and principles, do not tell us whether these intellectual experiences are the gifts of mathematics bestowed upon its devotees only, or upon the nonmathematicians as well. To the professional mathematician there is no "royal road" to mathematical wisdom except through the time established road he himself has taken. The person who is seeking to deal intelligently and understandingly with the supreme realities of life regarding science, ethics, social institutions, economics, politics, education, philosophy, and religion desires an understanding and appreciation of the great and basic concepts of mathematics, but not at the price of becoming an expert mathematician.

"A discussion of mathematical education, and of ways of enhancing its value, must be approached first of all on the basis of a precise and comprehensive formulation of the valid aims and purposes of education." This is the opinion of the National Committee on Mathematical Requirements, which represents the crystallized opinion of the teachers of mathematics. However, this is a subtle way of dodging the issue. Since the professional educator has delegated unto himself the authority of deciding what constitute the aims and purposes of education, we are advised to determine our aims and objectives of mathematics to conform to those of education. This is at least a simple and definite procedure provided we can find a definite statement of the aims and purposes of education, and one to which most of the leading educators subscribe. But a terse analysis of the aims of education as stated by various educators, or even the definition of what the educative process is, shows quite definitely that educators are far from agreement among themselves. Three illustrations will be presented to show the divergent viewpoints of the aims and purposes of education, illustrations which are not isolated opinions but characteristic of the different schools of thought.

First we have the conception that education is preparation for right living. As expressed by Bobbitt: "Education is to prepare men and women for the activities of every kind which make up, or which ought to make up, well-rounded adult life; it has no other purpose; everything should be done with a view to this purpose; nothing should be included which does not serve this purpose."

The second point of view of the purpose of education is that of the development of desirable habits. As expressed by Hanus: "The purpose of education is to discover and to develop the dominant interests and powers of pupils, and to develop desirable habits of thought, achievement, and conduct."

The third viewpoint as expressed by Morrison is: ". . . . the learning products which constitute that process of individual adjustment to the world which we call 'education,' and which are the objectives of teaching, are either attitudes or special abilities or skills."

That the students of the pedagogy of mathematics have

actually tried to conform to the suggestion of the National Committee on Mathematical Requirements is evidenced by the fact that, in the attempt to determine definite objectives for mathematical instruction, they have employed the following bases: (1) aims of education; (2) major life activities; (3) child activities; (4) existing objectives; and (5) functions of mathematics.

The aims of education, as we have already observed, are too broadly stated, and often do not clearly demonstrate what particular type of training the individual is to receive. Keyser contends that each type of education, such as the industrial and the humanistic, has its own aims and purposes, consequently, its own corresponding materials of instruction. He points out that: "The humanistic education has for its function and aim to lead the student into a clear knowledge of the standards of excellence of each of the distinctively human activities, and to give him a vivid abiding sense of their authority in the conduct of life." The industrial education, on the other hand, has for its aim and ideal, "to detect in each youth as early as possible the presence of such gifts and propensities as tend to indicate and to qualify him for some specific form of calling or bread-winning craft; then to counsel and guide him in the direction thereof; and finally by way of education to teach him those things which constitute 'the tricks of the trade'."

Following Herbert Spencer's list of Major Life Activities, curriculum makers have analyzed life into its major fields of activities. The activities as classified by the Commission on the Reorganization of Secondary Education, commonly known as the Cardinal Principles of Secondary Education, have played a very important role in the determination of not only the aims of education in general, but also the specific objectives of each separate field, such as mathematics.

However, the practice of formulation of objectives in the teaching of mathematics to fit certain arbitrary criteria consisting of major activities of life, has been reduced in essence to the practice of selecting a certain distribution curve and then trying to find data that fit the curve.

The practice of using child activities as a basis for the discovery of general tendencies in human behaviour and the understanding of the laws of learning has carried over into the field of curriculum making, and of the aims of edu-

cation. Invariably the analysis of child activities has been supplemented either by adult opinion, or else by an analysis of such activities that are surmised to constitute the types in which he may engage in the future. The practice at the best can only supplement other criteria for the determination of the aims of mathematical instruction.

The practice of analyzing existing objectives in the determination of course objectives has been used successfully by many investigators. It consists of a systematic listing of the aims obtained from various sources and an analysis of their importance both in the light of their frequency and the rating given them by competent authorities in the field. This method, being based upon the aims which are supposed to be already determined, does not solve the problem of what mathematical concepts, principles, and processes might be of advantage to the student if they were included in our present courses. The authority to whom the list is submitted for rating may or may not include additional aims, and if he does, the added aims are not often the result of serious study and investigation.

The aims and purposes of a subject, such as mathematics, can best be determined on the basis of the nature of the subject, the role it has played and it still plays in the practical, the intellectual, and the spiritual life of the world. As stated by the National Committee on Mathematical Requirements: "The primary purpose of the teaching of mathematics should be to develop those powers of understanding and of analyzing relations of quantity and of space which are necessary to an insight into and control over our environment and to an appreciation of the progress of civilization in its various aspects, and to develop those habits of thought and of action which will make these powers effective in the life of the individual."

A correct and adequate interpretation of the intrinsic values of mathematical instruction embodies in it the aims of education as applied to mathematics. Such interpretation must make it clear whether mathematics is a collection of technical abilities and manipulations of specific processes, or a unique method of thinking. Whether it is closely associated with the common activities which require like processes of thought, or devoted mainly to a peculiar domain of thought. And further, if mathematics be interpreted as

a method of thinking, the most excellent achievement of the race, in the conceptual world, according to the opinions of its devotees, then our problem is to determine in what fashion it may be used by the educated, the thinking, man in the handling of ideas, in the apprehension of the relationships between the ideas, and in the understanding and appreciation of the quantitative and spatial relationships which reflect the various aspects of civilization. If mathematics is a universal language for the study of order, harmony, symmetry, transformation, invarience, and law, then it is our problem to find out in what specific way the educated man may use this language both in the quantitative world of form and the general domain of thought. If it is an instrumentality in the recognition, observation, determination, and expression of relationships in all natural phenomena, then we must point out its unique services to the enquiring mind which seeks enlightenment. And if mathematics is all this and more then surely its concepts, principles, and processes should be understood by the educated person in the exercise of his traits, attributes, and powers in all thought processes. Otherwise the primary purpose of mathematics in the development of the powers of understanding and analyzing our environment and civilization are but empty and meaningless phrases.

Our investigation is based upon the assumption that mathematics is a method of thinking, and will endeavor to show how this method of thinking may be of definite service to the person seeking a general education.

Furthermore we concur with the interpretation of the educative process as having for its ultimate end the development of the powers of the individual to think and do. And to a great extent what he does depends upon what he thinks.

In order to determine the specific functions of mathematics, as a method of thinking, in the scheme of general education, we have selected for our definite task the determination of the mathematical concepts, processes, and principles which ought to be accessible to the student of general education, who is constantly called on to use the thought processes. We do not claim that a college student is always an educated person, but he is selected as the best representative type of those who are seeking culture and general enlightenment.

Furthermore, we distinguish between two types of students in their relations to our problem of determining the unique functions of mathematics in general education. First, the student of average intelligence, and possessed of intellectual curiosity, who enrolls in the courses of the various departments of a college to learn something definite about the nature of these branches of knowledge, and about their contributions to the progress of our present day civilization.

The second type, also intelligent and equally endowed with clear educational ambitions, has already the ultimate aim of his college training in mind. He takes the required courses as integral parts of his program for specialization in a particular department. He focuses his attention and studies on the work of some particular subject in order to specialize in that subject.

Our program of study is centered about the former student, for we seek to determine the relations of mathematics to general education, and not to professional education, however desirable the latter might be as a subject for investigation. Thus the formulation of our problem for study is based upon the determination of the mathematical requirements of the student of general education.

More specifically, the investigation seeks answers to the following questions:

1. What mathematical concepts, principles, and processes does a student of general education need in his courses?
2. What mathematical concepts, principles, and processes might a student of general education use to advantage in these courses if he were in the possession of them?

SPEEDING ELECTRONS MAKE LARGE MOLECULES FORM.

By shooting high speed electrons into vapors of various organic substances, some new substances with larger molecules than the original ones have been formed at the University of Toronto here by Prof. J. C. McLennan and Dr. W. L. Patrick.

Grain alcohol, methyl alcohol, formaldehyde, acetaldehyde and acetone, simple organic substances, were used in these experiments. Gaseous hydrogen, methane and carbon dioxides were formed by the later decomposition of the yellow complex compounds formed under the direct action of the rays.

The initial clumping process, called "condensation" by chemists, is expected to assist in solving new problems of the structure of chemical compounds. Similar complex substances have already been formed by exposing organic vapors to the bombardment of radium gamma rays.—*Science Service.*

SPARK-RECORDED TIME INTERVALS AS APPLIED TO MODERN APPARATUS.

By GLENN M. HOBBS,
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The evolution of time measurement is an interesting study. It is hardly conceivable that time-recording apparatus better than the hourglass had not been conceived until Galileo in 1531 discovered the laws of the pendulum, and fifteen years later, Christian Huygens invented the pendulum clock. Very soon thereafter the seconds pendulum became the standard laboratory instrument for time measurement and has remained so for many years with scarcely an improvement other than that developed by Captain Kater, called Kater's reversible pendulum, or simply Kater's pendulum. In later years, of course, the stop-watch was invented and this was used for short intervals of time, the seconds pendulum being used for longer intervals.

Twelve to fifteen years ago, however, several physicists, of whom Professor C. R. Fountain now of Peabody College was probably the first, made use of some form of spark device for timing a freely falling body, using the vibrator of an induction coil to break the circuit at a uniform rate, the secondary terminals being connected to vertical wires between which the sparks passed wherever the dropping object might be located. In this case the spark interval had to be measured by timing the vibrator of the induction coil by drawing a piece of paper between the spark terminals at a known rate so that the number of sparks for a given period of time could be counted.

A few years ago the Warren system of synchronized clock control was introduced in the large power centers, which so regulated the number of alterations in the circuit that only extremely small departures from the standard 60 cycles per second, even during peak loads, ever occurred in the alternating current circuit—these variations being of the order of 1/10 of a cycle, equivalent to a time variation of only 1/600 second. Up to that time there had been no precise regulating device for maintaining a uniform speed in an alternating current generator so as to produce a fixed voltage and a period of exactly 60 cycles per second. Variations in the load naturally produced variations of greater or less magnitude from this stand and period of 60 cycles,

slight variations occurring at almost any part of the 24-hour period with much larger variations showing themselves at peak loads.

While the adoption of this synchronizing system has not become universal, the characteristics of the electric current in the power stations where it has been introduced are so constant that an electric clock, running only by the aid of this current, will furnish practically perfect time over a long period unless, for some reason, the current is interrupted. The working mechanism of this clock is a synchronous motor running on this perfectly timed circuit and naturally, if there are no variations in the period of the circuit itself, there will be no variations in the rate of the clock, thus giving a perfect timing agent. There are a number of evident advantages in this synchronized system which the industrial world has not been slow in adopting. While the promotion of efficient power-house maintenance has been an extremely important one for the public utility companies, this has been made to look rather insignificant in comparison with the wide adoption of electric clocks in all localities where the synchronized system is in effect. The adoption of this method has stabilized our time system to a surprising extent, and, in view of our closely interwoven industrial developments, we shall soon expect to see the system extended throughout the entire country.

For laboratory purposes, particularly for comparatively short intervals, this synchronized timing unit is ideal in many respects, and the transition from a timing unit using the vibrator of an induction coil to one having a vibrator acting under the perfectly synchronized alternations of the A. C. power line is easy. In the new system the discharges across the spark gap are already timed and therefore can be used in any experiment requiring such a time interval without the labor of determining the number of alternations per second, as in the early experiments, and at the same time with an accuracy far beyond the previous limit. Such a system is applicable particularly to experiments involving a freely falling body; "diluted" acceleration, such as in connection with a Fletcher apparatus or an inclined plane; Atwood's machine; or experiments with the inertia wheel, Fig. 1. The simple circuit required includes

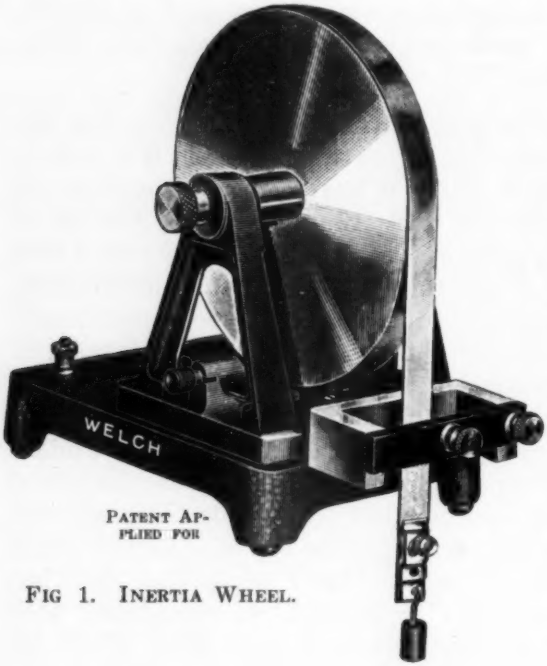


FIG 1. INERTIA WHEEL.

a high-tension source of current, some form of spark gap and a strip of paper so mounted that the sparks will pass through this paper and be plainly recorded upon it. This condition is best contrived by means of *coated* paper which records a definite change of color at the exact point where the spark passes through, thus making the record of each spark plainly visible so that measurements can be taken with accuracy.

Evidently two systems are possible, one in which the paper itself moves while the spark gap remains stationary, as in Fig. 1, the other in which the paper is held stationary between two clamps and the spark gap moves over the required distance with the paper between the terminals of the gap. In either case, the distance between any two successive spark marks on the paper represents the linear velocity of the moving object for that particular interval of time. While the easiest method of producing the sparking is from a point or a body to a contact plate, this method is open to criticism because the sparking does not take place at definite points. The best method is evidently a point-to-point discharge, as in this case the very nature of the spark gap reduces the spark "wandering" to a minimum. The spark gap need be only a matter of five or six millimeters and, therefore, the location of the spark is very accurately fixed

by the nature of the sparking device. Actual experiments made with a simple harmonic motion apparatus using a point-to-plate and later a point-to-point spark-recording device showed decidedly better results in the latter case.

FIG. 2

GORTON INTERVAL TIMER.

Given a spark gap, the next step is some device which will produce electrical impulses across this spark gap at definitely measured intervals. Professor F. R. Gorton has devised such a device in which a vibrator is energized by means of the impulses sent by an alternating current through a coil surrounding this vibrator, Fig. 2. To prevent excessive sparking this coil is actually in series with the secondary of a step-down transformer, the primary of which is connected directly to the A. C. circuit. Contact points are provided on the side of the vibrator so that any circuit connected to these contact points will have the current broken exactly 60 times per second. The binding posts leading from these contact points must, therefore, be connected through a battery to the primary of an induction coil, the secondary of which is connected to the spark gap. The primary of the spark coil, having pulses passing through it at the exact rate of 60 times per second, in turn produces sparks from the secondary at exactly that same rate. Therefore, the record of the sparks on the paper forms a very accurate method of permanently registering these time intervals. Having this record of the exact time intervals along the path of a moving body, the distances between successive sparks will represent the spaces covered during these time intervals and will, therefore, be numerically equal to the velocities of the object at these successive instants. Manifestly it is only necessary to measure these velocities and take their differences to determine the acceleration of the body for the time interval used.

A variation of the 60-cycle timer described above, also

suggested by Professor Gorton may be provided by properly loading the vibrator so that it will by a process of integration, combine the sixty impulses per second into thirty, although driven by the same alternating current. A device with the slower period will oftentimes be preferable, as an interval of 1/30 second may be better suited to the acceleration developed in a given experiment.

The requirement of still lower speeds makes necessary another instrument of the mechanical type, Fig. 3, which does not depend at all upon the alternations in an electrical circuit, but produces interruptions by virtue of the rotation of the shaft of a spring motor mounted in a proper housing. With such a timer definite time intervals may be produced over a range from, say, 40 r.p.m. to 150 r.p.m., a simple battery current being introduced through the contact points into the primary of the high-tension coil previously referred to, so that sparks from the secondary of this coil will be produced at perfectly determinable intervals. It will only be necessary in this case to time the revolutions of the mechanical timer with a stop-watch in order to measure the fundamental interval thus provided. There are conceivably many cases where such an instrument would be decidedly preferable either to the 60-cycle or to the 30-cycle apparatus. However, these three instruments evidently give a sufficient range of intervals so that the proper instrument can be selected for almost any experiment involved.

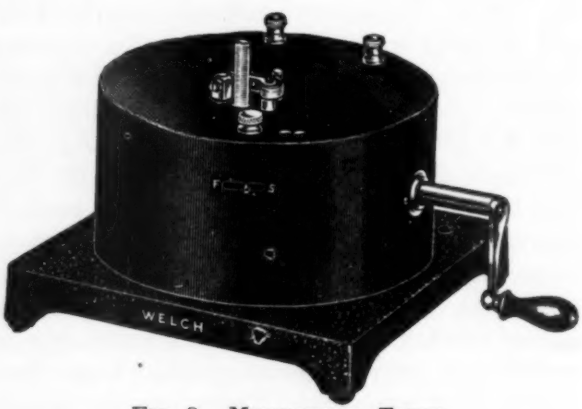


FIG. 3. MECHANICAL TIMER

The electrical interval-timers above described will provide the required accuracy only in case the circuit supplying the power is a part of the synchronized system. While this

system is very widely adopted, as already stated, there are some localities throughout the country which do not operate under this system and, therefore, if these or any other type of spark-recording instrument dependent upon the A. C. current are used there will be a varying error, depending upon the characteristics of the power plant furnishing the current, which will for most laboratory experiments produce much too inaccurate results.

In such cases there are several ways in which this error may be avoided. One natural way is to avoid the use of spark-recording devices, trusting the measurements to other less modern but extremely effective methods. Another way, however, is to make use of some type of impulse counter which will record the exact rate at which the alternations are being furnished in the particular A. C. circuit involved, Fig. 4. Such a device will be some form of synchronous motor much the same as in an ordinary electric clock, with a graduated dial and a sweep hand which marks in one complete revolution exactly 3,600 electrical impulses—the accurate measure of 1 minute of time if these electrical impulses are rated at 60 per second. It is only necessary, therefore, when using an unsynchronized circuit, to place the Frequency Counter in parallel in the A. C. circuit and observe by means of a stop-watch during the progress of the experiment the actual time taken by the hand of the Frequency Counter to register one or more complete revolutions. The observed intervals can then be reduced to the correct values. Repeated observations, particularly at laboratory times, may disclose that the circuit in one's laboratory repeats itself with sufficient accuracy to allow the use of a constant value. For example, if the variations from the standard 60

FIG. 4. FREQUENCY COUNTER.

cycles are due to inaccurate instruments but the control of the generators is good, observations taken on this circuit and properly corrected will be consistently accurate. On the other hand, if variations due to peak loads are discovered in the circuit at variable intervals, no standardizing program will be possible and the observations must be taken at the time the experiment is performed.

The measurement of time intervals in the laboratory by spark-recording apparatus is here to stay. In most experiments utilizing this apparatus, the time enters into the calculations as the square, and as laboratory men become more and more familiar with its use and see the advantages of reducing the most fruitful source of error (the time element) to practically zero, they will be more inclined to adopt the method.

FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE.

BY DUANE ROLLER,

The University of Oklahoma, Norman, Okla.

The fact is, that civilization requires slaves. The Greeks were quite right. Unless there are slaves to do the ugly, horrible, uninteresting work, culture and contemplation become almost impossible. Human slavery is wrong, insecure, and demoralizing. On mechanical slavery, on the slavery of the machine, the future of the world depends.—*Oscar Wilde.*

There is no serious attempt in progress to make machinery systematically lighten toil but only to make it increase profit. —*Norman Thomas, the leading exponent of Socialist doctrine in the United States, in his illuminating and constructive new book "America's Way Out: A Program of Democracy."*

This machinery of ours is something new under the sun. And the failure to recognize it as such impairs the value of many brilliant and profound attempts . . . . . to read our future in the light of our past.—*Norman Thomas, "America's Way Out."*

We know the truth, not only by the reason, but also by the heart.—*Blaise Pascal, "Thoughts."*

One of the finest and most noble characteristics of modern investigators, which distinguishes them so worthily from the crazy dogmatists of earlier times, is that, whenever they recognize the errors of their new theories, they resolutely abandon them.—*René Fülöp-Miller, in "The Power and Secret of the Jesuits."*

THE NEED FOR A MORE SOCIALIZED EMPHASIS ON CHEMISTRY AS TAUGHT IN THE HIGH SCHOOL.

By Bruce H. Guild,

Senior High School, Iron Mountain, Mich.

(By socialized emphasis is meant that emphasis on both the content and subject matter that best adapts itself to the nature of the pupil as he is, and to his needs in the society in which he lives.)

It is interesting to trace the part that the subject of chemistry plays in our program of education. It must be remembered that chemistry is a very new science. It first emerged from its origin in alchemy scarcely more than a century ago. The chemistry of metals, pottery, fire, bread, tanning, etc. were rule of thumb processes with little or no scientific basis. It had very few or no practical applications for some time and it was rightly included in the realm of natural philosophy because of its abstract and uncertain nature. Later on, as the science developed and its practical applications to medicine and industry became more pronounced, it was rather widely included in the high school curriculum. At the time when it became established in the curriculum the main purpose of the high school was to train for college. As few people finished the high school course in those days, and the knowledge of the subject was much more limited than at present, this was a perfectly proper thing to do. However, since the part played by the high school is now a different one and practically everybody graduates from the high school, and since much of the traditional subject matter of chemistry still remains, let us examine the situation in the light of present social conditions and needs.

There are several facts that need to be considered. First, the science of chemistry is such a living, growing subject and surges ahead with such leaps and bounds that it is impossible to keep up to it with all of its new ramifications and uncertainties. It is especially difficult when the subject is being taught to immature persons by teachers whose training would unavoidably be limited. The working tools, or the mechanics of the subject are becoming so complex that it is impossible to teach it truthfully and thoroughly without making many unscientific generalizations. If the subject is taught with primary emphasis on the mechanics of the science such as laws of valence, equations, and complex

calculations that are beyond the mental grasp of the average student, it comes to have about as much social value as the study of algebra does for girls. While it is true that a certain amount of the fundamental processes are necessary to enable one to appreciate the cultural side of the subject, we can make a comparison to the study of literature as it is taught in the high school. A certain amount of the fundamental processes are necessary but we do not spend much time on the fine points of formal and creative writing. A great part of the time in courses of high school English is spent in the appreciative study of the creations of others. Outside of those fundamental processes that the average person will use in his everyday life there can be no social value to a study of them to an extent that is common in the course of study of the average chemistry course as it is taught today. It therefore seems valid to form the conclusion that in the face of the growing complexity of the fundamental processes of the subject of chemistry, it is no longer socially justifiable to make the means the end, as we tend to do to large extent at the present time. There is too much emphasis on the mechanics of chemistry and no use that the average person can make of it because of its complexity.

Let us look at a second fact that seems to substantiate the thing that has just been mentioned. When students who have taken language in high school go to college they are given credit for their work inasmuch as they can enter in advanced classes in the subject. It is common for one who has had two years of a language in a high school to commence his college work in the subject by entering the second year class. Students entering college and taking up the study of chemistry are usually not given any credit for their high school work and enter classes whose course of study is almost identical to that of the courses for those who have had no high school chemistry. I have been told by one college professor that he would rather have a beginner who has had no high school chemistry because of the wrong techniques and false notions that have to be unlearned before progress can be made in the course. This fact seems to indicate two things, first, that the mechanics of chemistry are not standardized and are changing so fast that there

would necessarily be great differences both in kind and degree, and second that what learning of the high school course is valid is soon forgotten because of its abstract nature and uselessness. Therefore this second fact seems to again indicate that emphasis placed on the fundamental processes is not socially valid because of its uselessness and temporary nature.

Let us look at the problem from another angle. Chemistry touches the life of every person. The water we drink, the food we eat, the clothes we wear, all are prepared through some chemical process. In this modern age of science no phase of science has so much to do with the life of the average person. The field is so complex and the applications are so many that it is vitally essential to the cultural education of every person that they know *about* chemistry and the part that it plays in their lives. Much of our reading is unintelligible without a little knowledge about chemistry but please note that I am not referring to the mechanics of it. For example, when the Graf Zeppelin was in the limelight it was to the cultural advantage of every one to know that hydrogen was the lightest element, highly inflammable and explosive, but what difference did it make whether the reader could calculate how many grams of hydrogen could be obtained from the reaction of ten grams of zinc with sulphuric acid, and how many liters of space said amount of hydrogen would occupy under standard conditions of temperature and pressure, and what this volume would be if the pressure were raised to 790 mm. and the temperature was increased to 20 degrees centigrade. Yet these things constitute a part of the standard curriculum in chemistry. On the other hand the knowledge about organic chemistry is sadly neglected and the average student usually never gets far enough along in the course to know what Bakelite or Karolith are and perhaps the reason for this is that we feel that he should not know this unless he can write the structural formulae for them.

Let us then sum up and make our final conclusions. First, chemistry has become so complex and dynamic that the fundamental processes and mechanics of the science are not of much value in our curriculum because of their complexity and difficulty of attainment on the part of the aver-

age high school student of today who represents every man and not the select few who will go into chemistry or some phase of it as a profession. Second, chemistry has so many applications to the life of the average person that knowing what it is and what it does is of more importance than just exactly how to do it. Therefore, in the teaching of the subject, in order to give it its correct social emphasis, which is after all the truest criterion of its worth, it is necessary for the teacher of the subject to carefully evaluate the content of the course of study and put the proper emphasis on those phases of it that will best adapt themselves to the nature of the individual and his needs in the society in which he lives. This means that much can be removed from the ordinary text and course of study that deals with the mechanics of chemistry, the formulae, the calculations, etc. Only enough of the fundamental processes should be included to make intelligible the things that the student will learn about. It also means that much must be added that is of a cultural and appreciative nature, such as is found in "Creative Chemistry" by Slosson, the "Story of Chemistry" by Darrow, and many other excellent books of that nature. The general trend of chemistry teaching is now in this direction but texts and courses of study still lag to a considerable extent, and there is much to be done by the wide-awake teacher in meeting the social needs of the student.

THE MENG.

By F. M. Denton, *The University of New Mexico, Albuquerque, New Mexico.*

It is now many years since Professor Perry proposed the name *slug* for the engineers' unit of mass. The choice of name was unfortunate. The slug has failed of adoption because its name is ill-chosen. I suggest the name *meng* for the same unit. It has the right initial letter for a unit of mass and it is an obviously suggestive abbreviation for "engineers' unit of mass."

The need of a name for this unit (namely, the amount of mass to which the engineers' unit of force—one pound weight—imparts unit acceleration—one foot per second per second) is undoubted. The majority of good students leave college with but hazy ideas about the dimensions of such quantities as moment of inertia. Using engineering units the student is apt to say moment of inertia is expressed in "lb-ft. squared" when he ought to say "engineers-unit-of-mass-ft. squared," or "slug-ft. squared" or better still "meng-ft. squared." The meng is the amount of mass in a body which, at Greenwich, weighs 32.2 pounds.

THE PROJECT METHOD IN HIGH SCHOOL BIOLOGY.

By M. M. Mandl,

Evander Childs High School, New York City.

Children, especially those of the younger high school age, are mostly motor-minded. They learn best by "doing." If this "doing" be properly supervised and guided, its effects on the child may be most decidedly wholesome and beneficial.

The sciences furnish a wealth of material for self development and improvement on the part of the student. They afford numerous opportunities for the teacher to enrich the curriculum of those pupils who would otherwise develop habits of laziness because of the possession of a superior intellect which requires little effort to maintain a high average in a class with only average students. Unfortunately our present crowded curricula make it practically impossible for the teacher to do much project work in the classroom. However, a teacher who loves his subject, and who has the best interests of his pupils at heart, can accomplish manifold and undreamed of results by the judicious use of a little time after school, with the theft (?) of a few occasional minutes from the regular recitation.

The writer assigns a project to each student in his classes. These projects are carefully evaluated, and included with the other work of the term in grading the pupil. Each student receives a list of suggested projects covering the work of the term, with a brief description of each. He is told to make a selection of the three subjects he prefers, in the order of his preference. Occasionally a student requests a subject which is not listed among the regular projects. If this is related to the work of the term and offers possibilities of development, it is assigned. As far as possible the first choice is given each student, although an effort is made to avoid repetition of projects within the same class.

As soon as the pupil has chosen his topic he receives a set of mimeographed directions giving the various suggestions as to method and materials. These suggestions are included later, under "Suggestions for Biology Projects."

One method used successfully, but undoubtedly capa-

ble of great improvement, is the assignment, by the teacher, of different afternoons for illustrating the method of working with the various materials described in the suggestions. Thus, one afternoon could be devoted to work with plaster of Paris, another for work with soap, another for papier maché, etc.

It would probably be a very wise investment if the teacher purchased several small cans of oil paint in assorted colors for this work. He could thus guide the students in the proper selection of color schemes for the various projects where color is desirable. Danger is thus averted of hideous combinations of color which might otherwise ruin exceptional pieces of work. If the teacher encourages his pupils to do all coloring of projects in the classroom after school, he can supply the paints at a fraction of the cost required by the students purchasing them individually.

Of course if the teacher undertakes this work he must expect to have students waylay him at every turn of the road, asking advice on numerous problems which arise. But as questions are the surest indications that the child is learning—and thinking—the teacher should be highly gratified at this symptom, although it may sometimes have its disconcerting moments.

One of the arguments against requiring a project from each student as suggested in the foregoing is that they are time-consuming. This is sometimes a valid criticism. A student may have five teachers each day. It is not unusual for each teacher to assign a heavy burden of work, due to failure to consider that the student has other teachers who may do likewise. To avoid this criticism, the projects may be assigned early enough in the term, to enable the student to complete his project during week-ends, or when his other assigned work is lighter than usual.

Another criticism is that considerable material is wasted, sometimes on the part of students who cannot afford any great expenditure. For such pupils, however, who feel that they cannot spend the few cents needed for materials, it is possible to assign term themes, charts, or it may be possible to give them some materials from the

supplies of the department. There are numerous friends of our children who are glad to grasp an opportunity to supply them with funds for supplies, or medals and other prizes to stimulate initiative and greater effort. More will be said on this subject later.

Another criticism which may be justified, is that the teacher may allow his enthusiasm to carry him off his feet, thus permitting this system of projects to eat into the class time to an appalling extent. This would vitiate much of its good by holding up the progress of the class in the general subject matter. If the teacher follows a definite plan of study, he can determine how much time he can devote to his projects in the classroom. It is not always easy to get a student to wait till after school to bring his momentous problems to the teacher for solution or advice, but it must be done in as tactful a manner as possible.

Other criticisms will probably present themselves—but experience would seem to indicate that the benefits derived more than compensate for the losses entailed.

How does the child benefit from his project-making? First he must get a clear understanding of the subject matter in order to properly illustrate it and picture it to others. While it is true that it may not help him in other branches of the subject, it stimulates thought along one branch, with a possible tendency to arouse a similar reaction toward others.

Projects undoubtedly create and stimulate interest in the subject under discussion. Students are interested in each other's problems. They compare notes. They offer suggestions and criticisms to each other. Meanwhile, they are learning something by observing the subject in a live, dynamic way.

Occasionally, the making of a project may indicate some latent powers or characteristics of the child which may help him determine his life work. An example of this sort (from a number observed) may be illuminating. A girl in a class of advanced biology students selected as her project, "The Evolution of Man." She had never used modeling clay before, but determined to make a set of reproductions of the heads of the primitive races

of man, from Pithecanthropus to Cro-Magnon. With no other material than some flat prints, she constructed an exhibit worthy of a sculptor. Her teacher is quite enthusiastic about her work, and has arranged for an interview with a prominent sculptor. What will be the result? It is interesting to imagine the possibilities. The child did not know of her ability along this line prior to her project in biology.

Frequently, the parent receives indirect instruction in biology through the project-making of his child. A teacher who conscientiously takes up this line of work will be astounded at the results a questionnaire to his students will bring concerning parental interest, and sometimes, cooperation in the completed projects. The teacher is accomplishing something else besides teaching the parent. He is creating a closer relationship between parents and their children, one which is frequently absent in the present era. The parent in seeking to help his child comes to a better understanding of the child's problems; the child realizes that his parent can often help him out of a dilemma.

What shall be done with the projects when they are completed? It would seem desirable to create a spirit of altruism among the students whereby they would be anxious to serve their school. Students would strive to have their exhibits considered satisfactory for classroom use. Thus we have the biblical saying, "Cast thy bread upon the waters," come true. The expenditure of time devoted by the teacher in the making of the projects is more than adequately repaid by the splendid illustrative materials which may develop under proper supervision.

The projects should be prominently displayed in the biology room. It is impossible for even a very stupid or lazy student to repeatedly sit in such a classroom without absorbing some biological principles. Even if he is inattentive, he will stare about the room to see what his fellow students have done. He will see some bright colors and will wonder what they mean. He is learning.

If these exhibits are changed from time to time, the children acquire the habit of observing them more closely. If the exhibits remain on display too long, the child loses

interest in them, although he continues to learn something from them. With a changing series of exhibits, they become more meaningful, and the room becomes less of a classroom and more of a biology room.

To secure projects of high caliber, and not merely half-hearted efforts, it is desirable to stimulate competition among the students. The teacher may call the attention of the class to particularly good projects. This will likewise cause other students to seek this special recognition by striving to make superior showings. Medals or cash prizes may frequently be obtained from parent-teachers associations, from clergymen interested in the school, from seed supply houses or other business firms, etc. In smaller communities special funds may be made available for this purpose by the Board of Education or the General Organization of the school. The cost of a silver medal is slight however, and if necessary may be purchased by the teacher.

Below are the "Suggestions for Biology Projects" handed out to students to aid them in this work, together with the list of the projects suggested in the various grades of biology.

SUGGESTIONS FOR BIOLOGY PROJECTS

1. Plan your project on a small scale before starting on your real project. Problems may arise which will necessitate changes in your plans, or it may be necessary to correct errors. It will save time and material to discover these difficulties before you start on the final project.

2. Materials:
   - (a) Plaster of Paris
   - (b) Modeling Clay
   - (c) Paper Mache
   - (d) Wood Carving
   - (e) Soap
   - (f) Miscellaneous

3. Preparation: For using materials (a), (b), or (c), it is desirable to have a strong board large enough to support the model. Broad-headed nails may be driven into the board on which the model may be constructed; or a frame of nails and wire, or wood, may be attached to hold the model. The model may, however, be constructed first, and attached to a board later by means of screws like that illustrated in fig. 1. Fig. 2 illustrates the construction of a form on which the model may be constructed (described above).

Fig. 1

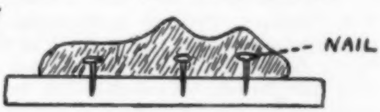


Fig. 2

4. Plaster of Paris: Plaster of Paris is a cheap material for use

in model making. It is a white powder that can be purchased at a very nominal sum—from 2c to 5c per pound, at any paint store. It should be mixed only when ready for use as it hardens quickly. Plaster of Paris may be poured into a platter or tray which has first been covered with a fine film of butter, vaseline or oil. This prevents it from sticking.

The Plaster of Paris should be stirred into a small quantity of water until it reaches the consistency of thick cream. This may either be used very much like modeling clay—that is, may be molded into place, or it may be poured into a mold for carving later.

If it is to be used as modeling clay it should be molded into the approximate shape wanted, by following instructions given in "3."

When poured into the receptacle prepared for the model, it produces a smooth finish on one side. This side should be used for the carving—or plaster paste should be applied to the nailed board directly, which will hold it firmly when dried. A drawing of the project should first be made on the plaster mold when it dries. It may then be carved easily with a kitchen paring knife or pocket knife. If the plaster be moistened again it will usually carve more easily. Judicious use of paint or crayon on the dried completed project helps in pointing out or emphasizing special parts. India ink may also be used to bring this about.

5. Modeling Clay: In making modeling clay projects it is desirable to place the model on a varnished board, or some object which will not show the oil stain caused by the clay. Modeling clay has both advantages as well as disadvantages. It is very pliable, and errors or changes can easily be made. On the other hand modeling clay always remains soft, and requires greater care in handling. It is desirable to construct the model on a board as shown in fig. 2, to avoid having the model slide or fall from the board, and also to permit handling without injury. In working on modeling clay various home-made tools can be constructed. An orange stick is very convenient. Bristles of a brush may be used as cilia, and if the student is especially adept it is possible to make glass organs which can be inserted in the clay. The entire model can be colored by an oil paint.

6. Paper Mache (Papier Mache): This is made from old newspapers which are torn up into small pieces, soaked in water with possibly a small amount of glue added. The paper is then kneaded into a pulp which turns it into a creamy consistency. This is a common material used in elementary schools in the construction of maps, etc. It is very light when completed, is easily handled, and does not easily break. The pulp is treated very much like modeling clay. It can easily be pressed into various shapes, and will take either water color or oil paint easily. In general the same procedure may be followed as described in No. 5.

7. Wood Carving: Some boys in the class and a few girls may be particularly skilful with tools. For them it will be possible to suggest wood carving models. A coping saw or fret saw can be used to construct patterns of intricate design, which can be nailed or glued together to form almost any kind of model desired. With some wood filler, and the proper addition of modeling clay or putty some exceptional work may be secured.

8. Soap: Proctor & Gamble has issued some very illuminating pamphlets on soap carving. For this purpose it is desirable to use a fairly fresh piece of soap. Dried soap will not carve easily but will chip and break. Probably the best soap for model making is Ivory soap. The kitchen knife (paring knife) is a good tool. This may be supplemented by an orange stick, a nail file, and others. If the soap breaks it is possible to glue it together with a strong fish glue.

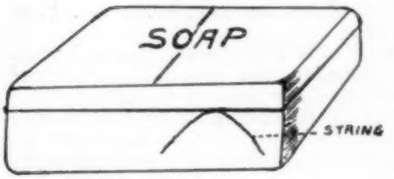


Fig. 3

If larger models are desired than may be obtained from one piece of soap it is possible to glue several pieces together in this way. If the model does not require much depth it is possible to cut one piece of soap into at least three pieces by using a string and pulling it together as shown in Fig. 3. The parings may easily be used in the laundry. Models may be carved in relief, so as to stand out, or may be carved into the soap so as to be indented. The completed soap model should be painted to bring out differences in structure, etc., but before being set aside it should be coated with a thin coating of clear shellac. This is necessary to prevent the warping of the soap due to drying. The model treated in this way may last forever. Models should be attached to a board for handling. Hooks shown in fig. 1 may be used for this purpose.

9. Charts: For charts it is advisable to secure either a heavy white or colored cardboard, or a Smith Chart (obtainable through the school or from one of the supply houses). (The Smith chart is more expensive than the other cardboards but has brass eyelets already attached.) A piece of glazed cloth or oiled cloth may also be used, and may later be attached to a window shade roller.

The drawing should first be made very lightly in pencil so that erasures may easily be made. It should be large enough to be clearly visible at a distance of about 35 feet. Where charts are to be used, it is most advisable to make a complete drawing on a small sheet of paper, including labeling, etc., so as to properly space the material and avoid crowding. All printing should be horizontal, and should have label lines pointing directly to the objects they name.

All lines should be in India ink, and should be fairly broad. This is necessary so that the students in back of the room may see the chart clearly. Paints help greatly in making important parts stand out.

10. Miscellaneous Materials:

a. Actual Specimens: Specimens such as leaves, insects, skins, etc., may be dried and mounted on boards or in small vials or capsules, which may be attached to a board. They may be attached by wires or strong thread which may be passed around the objects and fastened back of the board or chart supporting them. Adhesive tape may also be used to fasten objects, but is not as neat nor as strong.

Fig. 4 Methods of attaching specimens.

b. Preserved Specimens: Specimens such as soft bodied animals may be preserved in vials, small bottles, etc., in formalin or alcohol, and may be mounted as shown in "10 a" above, or may be placed in Riker mounts or other glass-fronted cases. They will frequently show up better if the back of the vial is painted black for white or light colored specimens, and white for dark colored specimens. The same effect may be produced by placing a colored paper back of the vial before fastening it into place.

c. Five and Ten Material: Frequently small models such as celluloid frogs, artificial flowers, etc., may be purchased in the 5 and

10c store or toy shop, and may be used to illustrate some biological principle. They often require coloring.

1st Note: When capsules are used it is inadvisable to use liquids as they sometimes leak out and disfigure the specimen. Colored powder, paper or silk may be substituted for colored liquids.

2nd Note: Various combinations of the methods suggested may be used. The student may also show a good deal of ingenuity by utilizing materials not mentioned in the foregoing, and not ordinarily thought of.

Suggested List of Projects by Grades

Biology 1.—Elementary Biology (first term).

1. Parts of a plant
2. Structure of a flower
3. Pollenation
4. Fertilization in a flower
5. Adaptation of seeds for dispersal
6. Structure of a fruit (Bean)
7. Structure of a fruit (Apple)
8. Development of the bean pod (from the pistil)
9. Elements present in living things
10. A comparison of plant and animal cells
11. Preparation of oxygen
12. Preparation of carbon dioxide
13. Tests for nutrients with examples
14. Uses of nutrients to the body
15. Vitamin A
16. Vitamin B
17. Vitamin C
18. Vitamin D
19. Structure of the root
20. Structure of the root hair
21. Osmosis
22. Germination of bean seed
23. Germination of the corn grain
24. Digestion in a seed
25. Geotropism
26. Hydrotropism
27. Cross section of a woody stem
28. Cross section of a pithy stem
29. External structure of a stem
30. Path of liquids in a stem
31. Cross section of a leaf
32. Lower epidermis of a leaf
33. How the stomata work
34. Imprints of various leaves (or leaf collection)
35. Photosynthesis
36. Transpiration
37. Respiration
38. Conservation of plants
39. Yeasts and their importance
40. Bread Mold
41. Some important bacteria (show three forms)
42. Typhoid fever
43. Tuberculosis
44. Colds
45. How to kill germs
46. Beneficial bacteria
47. Economic importance of fruits and seeds
48. Economic importance of roots
49. Economic importance of stems
50. Economic importance of leaves

51. Life history of the moss
52. Life history of the fern
53. Important fungi
54. Forest products

Biology 2.—Elementary Biology (second term).

1. Ameba
2. Paramecium
3. Digestion in the protozoa
4. Respiration in the protozoa
5. Life history of the malarial parasite
6. Principle of the balanced aquarium
7. External structure of the grasshopper
8. Development of the grasshopper
9. Hind leg of the grasshopper to show adaptations
10. Life history of the housefly
11. Life history of the mosquito
12. Life history of the butterfly
13. Harmful insects
14. Beneficial insects
15. Methods of destroying insect pests
16. Life histories of important insect neighbors
17. Insects imported into the United States
18. External structure of the fish
19. The gill of the fish
20. Life history of the salmon or other fish
21. Conservation of fish
22. Adaptations of birds for flying
23. Beaks of birds
24. Types of birds' legs
25. Bird conservation
26. Nests of birds
27. How birds are beneficial
28. How birds are harmful
29. Poultry breeds
30. Importance of rats
31. Enemies of the rat
32. Importance of mammals to man
33. Trichina
34. Tapeworm
35. Hookworm
36. Digestive system of frog
37. Life history of frog
38. Structure of human skin
39. Types of muscles of the body
40. Human digestive system
41. Muscles of the arm
42. Human brain
43. Elements of the human body
44. Food adulteration
45. Peristalsis
46. Teeth of the human mouth
47. Importance of mastication
48. Digestion in the human body
49. The pancreas
50. The Villus
51. John Burroughs
52. James Audubon
53. Composition of the blood
54. Work of the white corpuscle
55. Circulatory system of man
56. Respiratory organs of man

57. Proper and improper ventilation
58. Conditions which destroy health
59. Effects of alcohol
60. Effects of tobacco on a growing person
61. Eugenics and euthenics
62. Work of the U. S. Dept. of Agriculture

Projects for Advanced Biology—first term.

1. A Typical Cell
2. Chemical Elements Present in Protoplasm
3. An Elodea Cell
4. A Spirogyra Cell
5. An Amoeba
6. A Paramecium
7. Examples of Protozoa
8. Stages in Mitosis
9. Structure of a Gene
10. The Cell Theory
11. Epithelial Tissues
12. Connective Tissues
13. Muscle Tissues
14. Nervous Tissue
15. Structure of a Nerve
16. Physiological Division of Labor
17. The Digestive System of the Frog
18. The Urogenital System of the Male Frog
19. The Urogenital System of the Female Frog
20. Experiment Illustrating Digestion
21. Value of Mastication
22. Food Nutrients: What They are and Examples
23. Vitamins: Their General Functions in Each Case
24. Vitamin A
25. Vitamin B
26. Vitamin C
27. Vitamin D
28. Vitamin E
29. Vitamin F
30. Vitamin G
31. The Thyroid Gland
32. The Pituitary Glands
33. The Adrenal Glands
34. The Pancreas as a Ductless Gland
35. The Duodenum and Its Functions
36. The Thymus
37. The Liver and Its Functions
38. The Structure of the Small Intestine
39. Structure of the Stomach
40. The Lymph System
41. The Digestive Enzymes
42. The Composition of the Blood
43. Clotting of the Blood
44. The Circulation of the Human Blood
45. The Structure of the Heart
46. Structure of a Gland
47. Structure of the Kidney
48. Structure of the Skin
49. Hydrotropism
50. Geotropism
51. Structure of the Brain
52. Structure of the Spinal Cord
53. Reflex Action
54. The Autonomic Nervous System

55. Reflex, Habit and Thought Actions Compared

Projects in Advanced Biology—second term.*

1. Asexual Reproduction of Molds
2. Sexual Reproduction in Molds
3. Conjugation in Spirogyra
4. Structure of the Flower
5. Binary Fission in Paramecium
6. Conjugation in Paramecium
7. Budding of yeast plants.
8. Other Asexual Methods of Reproduction in plants
9. Grafting Methods
10. Budding of Hydra
11. Regeneration in animals
12. Spermatogenesis
13. Oogenesis
14. Double Fertilization in Flowering Plants
15. Urogenital System of Male Frog
16. Urogenital System of Female Frog
17. Structure of Egg and Sperm (include comparison if possible)
18. Stages in Embryonic Development of an animal
19. Stages in Embryonic Development of an Angiosperm
20. Post-embryonic Development of the Frog
21. Variation in Animals (select any one form or more if desired)
22. Typhoid Fever
23. Jacques Loeb
24. Charles Darwin
25. Gregor Mendel
26. Incomplete Dominance in Animals
27. Incomplete Dominance in Plants
28. Complete Dominance
29. Weissman's Theory
30. Mutation in Plants or Animals
31. Luther Burbank
32. Good versus Bad Inheritance
33. Evolution of the Horse
34. Evolution of the Hoof of the Horse
35. Archaeopteryx
36. Comparison of Limbs of Vertebrates
37. Embryos of Vertebrates
38. How Germs Reproduce
39. Beneficial Bacteria
40. The Nitrogen Cycle
41. Smallpox
42. Tuberculosis
43. Diphtheria
44. Rabies
45. Tetanus
46. Louis Pasteur
47. Production of Antitoxin
48. How Germs are Spread
49. Our Body Defenses Against Germs
50. The Malarial Parasite

Advanced Zoology—Invertebrates.

1. Life Functions of Ameba
2. Life functions of paramecium
3. The vorticella
4. Shell-bearing protozoa
5. The volvox colony
6. The euglena
7. The malarial cycle

8. Grantia sponge (entire; long. section; cross section)
9. The sycon type of sponge
10. Model of a commercial sponge to show internal structure
11. Reproduction of hydra
12. Longitudinal section of hydra
13. Cross section of hydra
14. Alternation of generations in Obelia
15. Operation of nematocysts of hydra
16. The sea anemone
17. Different types of coral reefs
18. Theories of coral atoll formation
19. Internal dissection of starfish
20. Water tube system of starfish
21. Digestive system of starfish
22. Nervous system of starfish
23. Embryology of sea urchin
24. External structure of earthworm
25. Dissected earthworm to show internal structure
26. Cross section of earthworm through posterior region
27. Dissection of earthworm to show nervous system
28. Structure of earthworm (lateral view)
29. Trichina in human muscle
30. Life history of trichina
31. Life history of hookworm
32. Life history of liver fluke
33. Regeneration of planaria
34. Life history of tapeworm
35. Dissection of clam to show internal structure (digestive system, etc.)
36. Internal of clam with one shell and one mantle removed
37. Mechanism for opening and closing shells of clam
38. Structure of gills of clam
39. Glochidium of clam
40. Internal structure of oyster
41. Labeled collection of mollusc shells
42. The masticating apparatus of a snail
43. Internal anatomy of a spider
44. Spinning apparatus of a spider
45. External anatomy of a lobster
46. Dorsal dissections of a lobster
47. Lateral dissections of a lobster
48. Degeneration or specializations in crustacea
49. External structure of grasshopper
50. Respiratory system of grasshopper
51. Mouth parts of the grasshopper
52. Internal anatomy of a grasshopper
53. Life history of grasshopper
54. Life history of dragon fly
55. Adaptations of grasshopper for flight
56. Life history of the cabbage butterfly (or some other lepidopteran)
57. Life history of the house fly
58. Life history of the mosquito
59. Life history of the beetle
60. Life history of the honey bee
61. Labeled collection of insects
62. Comparison of insect mouth parts
63. Protection and mimicry in insects
64. Harmful insects (in relation to agriculture)
65. Beneficial insects
66. Insects imported into the United States
67. Insects harmful in the home

Advanced Zoology—Vertebrates.

1. Larval Tunicate—longitudinal section
2. Adult Tunicate—longitudinal section
3. Digestive system of the fish
4. Lancelet—median section through notochord and nerve cord
5. Fish—circulatory system
6. Frog—digestive system
7. Frog—circulatory system
8. Frog—urogenital system—male
9. Frog—urogenital system—female
10. Development of the frog
11. Brain of the frog
12. Sciatic plexus of frog
13. Experiments to illustrate functions of parts of the brain
14. Poison apparatus of the snake
15. Digestive system of the bird
16. Embryo of the bird
17. Development of the feather
18. Types of birds' beaks
19. Types of birds' legs
20. Collection of birds' nests
21. Collection of birds' eggs
22. Evolution of the horse
23. Evolution of man
24. Vestigial evidences of evolution
25. Homologous evidences of evolution
26. Thomas Hunt Morgan
27. Intelligence of Animals
28. Migration of Animals
29. Structural evidences of evolution
30. Vertebrates that destroy harmful insects
31. Development of the fish
32. Stomach of the ruminant
33. Evolution of hoof of horse
34. Life of Audubon
35. Life of William T. Hornaday
36. Life of H. F. Osborne
37. Evolution of the heart in vertebrates
38. Degeneration in vertebrates
39. Gregor Mendel
40. Breeding of animals
41. Animals that have become extinct
42. Enemies of our wild birds
43. Archaeopteryx
44. Skeleton of the frog
45. Comparison of teeth of vertebrates
46. Mendelism in animals
47. Comparison of brains of vertebrates
48. Laws regarding geographical distribution of animals
49. Furs or animals used commercially
50. Life history of the flounder
51. Model of U. S. Fish Hatchery
52. Sexual dimorphism in vertebrates

ELECTROCHEMIST RECEIVES MEDAL.

The Perkin medal, a high honor in chemistry, will be presented January 8 to Dr. Charles F. Burgess, of the Burgess Laboratories, Madison, Wis., for his achievements in electrochemistry. The award is made by the American Section of the Society of Chemical Industry.—*Science Service.*

NUMBER—THE LANGUAGE OF SCIENCE.[1]

BY H. E. SLAUGHT,
University of Chicago.

Language in its commonly restricted sense is a system of words and sentences, either written or spoken, by means of which one person conveys thoughts or ideas to another. In its perfected form and with skillful use, language should convey ideas with ease, celerity and clarity, with the understanding that clearness of thinking is essential to clarity of expression. Applied science is a broad field of knowledge which has been gained by systematic observation, experiment, and reasoning and which has been coordinated, arranged, and systematized. Pure science is a body of knowledge based upon arbitrary or hypothetical assumptions and built up by logical processes which involve no observation of facts and no experimentation.

The most obvious example of pure science is mathematics when thought of from the standpoint of its logical foundations. But pure mathematics has become so woven into almost every branch of applied science that it is commonly thought of quite apart from its logical aspects and as such has been adopted, so to speak, into the family of applied sciences where it has become their official language in terms of which the results of their systematic observations, experiments, and reasoning are set forth. This is especially true of the physical sciences and is rapidly coming to be true of any other sicence in which quantitative analysis constitutes the basis of its observations and experiments. A notable example of this latter kind is the modern treatment of economics which has now taken on a decidedly mathematical aspect.

In general it may be said that any science whose observations and experiments involve the study of functional relationships or lead to the proper interpretation of statistical data is, in so far, making use of mathematics not only as a tool for further investigation but as the very language in terms of which the investigation is carried on and the results coordinated and systematized.

In speaking of mathematics as a tool for scientific investigation it should not be inferred that it is merely a tool, as

[1]Abstract of an address given before the general session of the Central Association of Science and Mathematics Teachers, Chicago, November, 1931.

some curriculum reorganizers would have us believe. On the contrary mathematics is a self-contained science on its own account and as such constitutes one of the most important disciplines that can be included in any school curriculum. In its higher reaches mathematics is in a real sense a pioneer leader in the forward march of the other sciences. While it may be, and often is, studied purely for its own sake, giving pleasure and profit to its devotees, yet it frequently happens that pure mathematical science paves the way for important advances in applied science.

In the foregoing we have spoken of mathematics as the language of science, whereas the topic of this address is "Number the Language of Science." But there is no incongruity in these two statements for, as we shall try to show, the science of mathematics which began in the cradle of the human race when men first learned to count, progressed haltingly through many centuries and then more rapidly in the eighteenth and nineteenth centuries, depending upon the gradual unfolding of the number concept in the mind of the race. We shall attempt to show that the evolution of number underlies the development of mathematics and that mathematics is one of the fundamental factors in the whole fabric of modern science.

As an example of this interdependence of number, mathematics, and applied science, consider the experimentation which led to the discovery of the law of falling bodies so long misunderstood but finally made clear by Galileo in the sixteenth century. In order to effectively formulate that law, after countless observations, a mathematical equation was necessary involving numbers for the measurement of time, space, velocity, and acceleration. Such an equation is

$$s=\tfrac{1}{2}gt^2+v_0t,$$

in which v_0 is the velocity imparted at the start. When s is given, this is a quadratic equation for t which is a special form of the general quadratic

$$ax^2+bx+c=0.$$

To gain a complete understanding of such a general quadratic equation cost the human race a titanic struggle lasting hundreds of years. It involved the invention of a number system including integers, rational fractions, signed numbers, irrational numbers, and complex numbers. It required a workable set of number symbols and of operational sym-

bols, including exponents and radicals. It led to the need of general or literal number symbols and of rules for operating on them, and finally it required the solution of an equation for the value of its unknown number by means of proper operations on its members. These various elements involved in the solution of the general quadratic equation taxed the ingenuity of the best minds in all the earlier ages. Special cases were handled by Diophantus in the third century but it remained for Bhaskara, the Hindu, in the twelfth century to completely set forth the general solution. But even then the full significance of the irrational and complex numbers encountered in this solution was not understood and did not become clear till the middle of the nineteenth century.

What we have said concerning the mathematical formulation of the law for falling bodies applies with equal force to practically every investigation in the domain of physics and mechanics. Of course very few situations in this domain are so simple as the case of falling bodies, and consequently the more recondite the principles involved the more complicated the language of expression becomes. For example, as a mild illustration, consider Van der Waals' functional relation between the pressure and volume of certain gases:

$$(p+a/v^2)\,(v-b) = RT,$$

and it will at once become apparent how necessary the mathematical formulation is for the purpose of detailed study of this principle.

However, there is a still deeper sense in which mathematics is fundamental to the development of science not only in the domain of physics but in many other domains. Namely, in any domain in which functional relationships involve the notion of rate of change. This means the language and principles of the Calculus, which, since the days of Newton, have become the most powerful means of enumerating and interpreting the hidden laws of nature. Even in the simple case of falling bodies, the terms velocity and acceleration take on their full significance only in the light of the Calculus. The derivative and the integral are the two great tools of physical science. Even in the realm of electricity, the great unknown, the Calculus plays a fundamental rôle. Any modern treatise on electricity would lead the

casual observer, or the recondite student, to conclude that what little we know of this mysterious agent is best expressed in the language of mathematics. It is said of Steinmetz that his greatest achievement was the elaboration of the mathematics of the alternating current, involving as it did a wide range of higher mathematics in which functions of a complex variable played a leading rôle.

With reference to mathematical formulation in other sciences than physics and mechanics, the following citations are significant.

(1) From a well known professor of chemistry: "While a good course in calculus will enable a student to do elementary work in physical chemistry, yet advanced students and research workers find it profitable to put much time on higher courses in physics and pure mathematics, since the development of chemistry is sure to be in the direction of more elaborate mathematical formulation of its theory."

(2) From a professor of physiology: "The biological sciences rest in the main entirely upon the fundamental sciences of physics and chemistry. Without adequate training in these, with all the mathematical preparation which such training presupposes, the biological student will be greatly handicapped if he attempts in later life to do serious original research in his chosen field."

(3) From a professor of biometry and vital statistics: "The mathematical training for study and research in biometry should include algebra, trigonometry, analytic geometry and calculus, together with a course in modern statistical methods of treating observed data, a discussion of probability and the normal curve, frequency curves, correlation, and curve fitting."[3]

(4) Finally, in any line of investigation involving statistical data such, for instance, as actuarial science or some phases of social science, it is absolutely essential that the interpretation of such statistics and the conclusions deduced therefrom be made by those broadly trained in mathematics as well as in the particular field in which the investigation is conducted. Otherwise all sorts of false or unwarranted deductions may result.

[3]For an extensive statement concerning the use of mathematics for record in the biological sciences, including biometry and vital statistics see the *American Mathematical Monthly*, January, 1925, pages 30-36.

Enough has been said to show that practically the whole domain of applied science speaks to a greater or less degree in the language of mathematics. This could not have been possible before mathematics itself had achieved its full development in the nineteenth century, and especially before the invention of the Calculus in the seventeenth century and still more especially before the advent in Europe of the Hindu-Arabic number system in the thirteenth century. In a very real sense the language of mathematics is the language of number, and hence it is appropriate to close this address with a brief sketch of the unfolding and development of the number concept in the human race.

The language of number, in its initial stage of counting, as well as in all its higher phases, was, and still is, far more difficult for the race than non-mathematical language. Primitive peoples everywhere have attained a workable language, often quite complete for general purposes, but invariably limited in number words and number symbols. In extreme cases only two or three number words are found. For example, "one," "two" and "many."

The earliest achievement of note in number language of which we have definite record, was developed by the Egyptians at least 3500 years ago. Their number symbols were quite complete but very clumsy in use, as shown in great detail in the Rhind Mathematical Papyrus now preserved in the British Museum. The Greeks, a thousand years later, tried their hand at number language and failed after two quite different attempts. The Romans likewise failed to produce a workable number system. These nations could excell in practically every other phase of human endeavor but they could not devise a number system suitable for much practical use in arithmetic. It remained for the Hindus to turn the trick by use of nine number symbols and a zero to denote place value. The Arabs put this system into circulation in Asia and Africa and finally in Spain. There it was found by Leonardo of Pisa and introduced into Europe in the thirteenth century where in the course of two hundred years it became the universal number language.

The vocabulary of the number language was at first limited to the whole numbers. Ordinary fractions were only slowly recognized as numbers. They caused the race a lot of

trouble—and still do so. The idea of negative numbers was a tough one for the race and did not get fully accredited till Descartes in the seventeenth century gave them a clear title to admission. Irrational numbers were still more difficult to comprehend and imaginary numbers were entirely outside the pale. It was not till the nineteenth century that these anomalous characters were finally understood and fully accredited as legitimate members of the number family.

The number concepts which lie back of number words and which are visualized by means of number symbols, together with the algebraic and transcondental operations upon them, constitute the foundation and background upon which the present vast structure of mathematics has been built and without which it could not have been developed. Hence in a very real sense the language of number is the language of science.

QUACK CURES FOR TUBERCULOSIS.

A peep into the records of healing nostrums and devices for curing tuberculosis discloses some interesting evidences of the credulity of human nature:

Preparations of kerosene and turpentine, selling at $5.50 per bottle; a mixture of alcohol, water and vegetable extracts claimed to be an herb medicine used by the Choctaw Indians; other preparations containing creosote and malt extract, turpentine and ammonia. The latter compound was called a "penetrating germicide" and its vendors claimed it would also cure pneumonia, influenza, rheumatism, lumbago, neuralgia, neuritis, locomotor ataxia and varicose veins—evidently running down the alphabetical list of ailments and selecting those most common. Investigation showed that the business of selling this mixture had been developed by a race track follower who obtained the formula from a race track veterinarian.

A sanatorium for tuberculosis offered a treatment of smoke from medicated wood piped in from outside; another advertised that patients were cured by a liquid brewed from 1320 different herbs! An inhalor placed on the market a few years ago at $50 gave out a "medicated vapor of dried herbs," and not long ago there was a veritable epidemic of cabinets sending "ozone into the lungs and blood."

Hundreds such commercial remedies have been investigated by the Federal Government through the Bureau of Chemistry and the Post Office Department and not one has made good its claims. Advertising clubs have helped to draw popular attention to these fakes; newspapers and magazines have refused to publish their advertising at any price; the Better Business Bureau has assisted with prosecutions, while many of the 2084 affiliated tuberculosis associations throughout the United States in numerous instances assisted in gathering evidence of the worthlessness of the claims of such charlatans.

A STRIKING EXPERIMENT.*

By Morris Wistar Wood,
Culver Military Academy.

There are a good many different experiments described in Physics textbooks, to illustrate the fact that a freely falling body has the same downward acceleration, whether it falls from rest or is projected horizontally. Most of these experiments, however, allow one ball to fall from rest, while the other is projected from approximately the same point. Your ears then tell you whether or not the two bodies strike the floor at the same instant. Let your eyes do it!

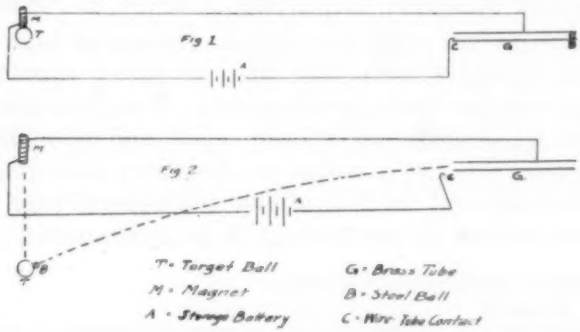
For some years the experiment described below has been used at Culver, and it never fails to bring out a great deal of interested discussion on the part of cadets. It could easily be duplicated in any Physics Laboratory of moderate size, without requiring any new apparatus.

A brass or iron tube, about two or three feet long and half an inch in inside diameter is *firmly* fastened in a horizontal position, at shoulder height, by means of a large clamp on a vertical post. We have some iron balls we use for specific heat or density experiments, which will fit snugly into this tube. At the other end of the laboratory from the pea shooter just described and perhaps thirty feet away a small electromagnet is fastened at the same height. Fifty or 100 turns of bell wire will do. It should be placed in a vertical position, and another iron ball, preferably two inches or so in diameter is suspended from this magnet when its circuit is closed. If such a ball is not available, a light wooden ball with an iron thumbtack in it will serve the purpose quite as well.

The circuit of the electromagnet is completed through any six volt storage battery and through a contact at the end of the tube, as shown in figure 1. When you blow through the tube, the magnet is released at the instant that the projected ball leaves the "gun" and the two will meet in mid air, as they fall at the same rate. If the "piece is carefully laid" so that the axis of the tube passes through the larger ball, it is almost impossible to miss. We find the

*This demonstration has been given by Professor A. L. Foley and his associates in the physics lecture course at Indiana University for many years, but as we have not seen it in print we are pleased to present Mr. Wood's description of it.—Editor.

two balls will meet eight or nine trials out of ten. If you blow hard, they meet near the magnet. If you take it easy, they meet nearer the floor. A laboratory apron makes



a good backstop, and a cardboard box under the magnet, on the floor, will register the misses.

By observing roughly the distance fallen through by the larger ball a fairly accurate approximation of the velocity, and time of flight of the projectile may be calculated. Try it some time. It's lots of fun, even if you believe, as I do, in international peace, and the world court!

FELLOWSHIPS FOR GRADUATE STUDY ABROAD.

Under the auspices of the various student exchanges of the Institute of International Education a limited number of fellowships are available for study abroad. These fellowships cover board, lodging and tuition in the majority of cases but the candidate must pay his own travelling and incidental expenses and should, therefore, have at his disposal at least $600.

The fellowships are offered in the following countries:—Austria, Czechoslovakia, France, Germany, Hungary, Italy, Spain, Switzerland.

General Requirements for Eligibility.

1. Citizenship in the United States or one of its possessions.
2. Holder of a degree of an institution of recognized standing, or a senior who will receive a degree prior to entering upon the fellowship.
3. Good moral character, intellectual ability and suitable personal qualities.
4. Certificate of good health.
5. Ability to do independent study and research.
6. Practical reading, writing and speaking knowledge of the foreign country in which the award is made.

Applications must be filed before February 1st, (and in the case of Germany before January 15). For application blanks and further information, address Secretary, Student Bureau, Institute of International Education, 2 West 45th Street, New York City.

CHEMISTRY TESTS AVAILABLE FOR USE IN HIGH SCHOOL CLASSES.

By Ralph E. Dunbar and Irving J. Grandy,
Dakota Wesleyan University, Mitchell, So. Dak.

This survey was made for the convenience of high school chemistry teachers who may wish to select standardized and other similar tests for class use. The tests are listed with a short description of each, price and publisher. It is hoped that this list contains all chemistry tests that have been published and made available for general high school use. Corrections or additions will be appreciated.

Gerry Test of High-School Chemistry

Forms A and B

Each test consists of twenty-five exercises of various sorts which test knowledge of chemical terms, formulas, and other information. 45 minutes.

Ginn and Company, 2301 Prairie Avenue, Chicago, Illinois, 60c per 30.

Powers General Chemistry Test

Forms A and B

Part one of each test deals with information about chemistry, and part two deals with the ability of students to do tasks in chemistry. The tests are carefully standardized and a key for scoring together with a helpful manual of directions is provided. 45 minutes.

World Book Company, 2126 Prairie Avenue, Chicago, Illinois. $1.00 for 25.

Glenn-Welton Instructional Tests in Chemistry

The tests consist of a series of thirty-six standardized tests, each covering a unit of work. They cover the essentials of any first chemistry course. They deal with chemical phenomena and principles, industrial processes, vocabulary, numerical problems, laboratory work, interpretation of diagrams, and biography. They give full attention to such essential topics as symbols, valence, formulas, equations, types of reactions, and families of elements. 40 minutes each.

World Book Company, 2126 Prairie Avenue, Chicago, Illinois. 36c each. Key 16c. Teacher's manual 16c. Prices subject to discount on quantity orders.

Rivetts Chemistry Test

Forms I, II and III

Tests cover the items of valence, symbols, formulas and other similar items. 1½ to 4 minutes each.

B. J. Rivett, Northwestern High School, Detroit, Michigan. Sample set 15c. 1c each in quantities.

Union Science Tests

Forms 1 to 10

There are ten tests in all. They deal with symbols, elements, oxides of elements, hydroxides of the elements, salts of metals, valence, meaning of chemical symbols, formulas, equations, chemical effects of heat, chemical effects of various agents, and naming of acids and salts. 2 to 10 minutes each.

Union Science Tests, 10109 Wilbur Avenue, Cleveland, Ohio.

Rich Chemistry Test for High Schools

Forms Gamma and Epsilon

Each form consists of twenty-five exercises covering chemical information, habits acquired in laboratory work, ability to think and to solve numerical problems. 25 minutes.

Public School Publishing Company, Bloomington, Illinois. Sample set, 20c. $1.00 for 25. Teacher's manual 15c.

Lyons and Carnahan Unit Drill Tests in Chemistry

The fifty-seven tests in this series deal with as many units of high-school chemistry. The special units cover the reading and writing of formulas, the chemical equivalent of common names, simple tests for cations and anions, and specific topics on applied chemistry. These should be selected by the instructor according to the time available and the work to be covered in the course. They are not standardized and are intended for practice and diagnostic purposes. About 45 minutes each.

Lyons and Carnahan, 221 East 20th Street, Chicago, Illinois. 1½c per copy.

Rauth-Foran Chemistry Tests

Tests I and II

These tests require the identification of substances, as elements, compounds or mixtures, the giving of the correct symbols or formulas for substances, the marking of a number of informational statements as true or false, the filling in of completion exercises, and the solution of problems. Test I covers the work of the first semester and Test II that of the second. Test I, 45 minutes; Test II, 52 minutes.

Catholic Education Press, Brookland Station, Washington, D. C. $1.00 for 25.

Iowa Placement Examinations, Revised, Chemistry

Series CA1—Aptitude; Forms A and B.
Series CT1—Training; Forms A and B.

The aptitude test deals with certain elements of mathematical ability, comprehension of selections taken from chemistry textbooks, and items of chemical and physical knowledge which are more or less commonly known. The training test deals with knowledge of chemical facts, including valence, formulas, and the ability to solve problems and write equations. 44 minutes each.

Bureau of Educational Research and Service, University of Iowa, Iowa City, Iowa. $3.50 per 100. Specimen set 45c.

The Technical Vocabularies of Public School Subjects: Subject Chemistry

This test is composed of seventy sentences. The student underscores one of four words which he considers as correctly defining the related word in the sentence. Valuable as a diagnostic test in determining the specific weakness of a class or an individual student. Time, variable.

The Public School Publishing Company, Bloomington, Illinois. Package of 35 for $1.50.

Columbia Research Bureau Chemistry Test

Forms A and B

The test consists of three parts. Part I contains 150 true-false items covering the most important material in the subject. Part II deals with equations. It contains equations that the student is to balance, reactions for which he is to write balanced equations, and reactions for which he is to write the equations without balancing them. Part III contains ten problems. 50 minutes for each test.

World Book Company, 2126 Prairie Avenue, Chicago, Illinois. Form A or B, $1.50 per 25. Specimen set for 20c.

George Washington University Series—General Chemistry Test

Forms 1 and 2.

The test consists of five parts. Part I consists of inserting the

omitted word in the sentence; part II with writing of formulas; part III contains 100 true-false items; part IV has 10 equations to complete and balance; and part V has five problems to solve. 50 minutes.

The Educational Test Bureau, University and Fifteenth Avenues Southeast, Minneapolis, Minnesota. $5.00 per 100, or 7c each.

Noll Tests in General Inorganic Chemistry

Achievement and Laboratory Tests.

The Achievement Test is intended to be used to measure students who have completed the course. Its three parts deal with laboratory technic and information, the drawing of simple apparatus and diagramming of the set-up of apparatus required in particular experiments. Achievement Test, 100 minutes; Laboratory Test, 60 minutes.

V. H. Noll, University of Minnesota, Minneapolis, Minnesota. Achievement Test, 6c per copy. Laboratory Test, 4c per copy.

The 20th Century Practical-Exercises and Objective Tests in Chemistry

This series of tests contains fifty-three practice-exercises and objective tests in chemistry which are designed to give a clearer and fuller understanding of chemical principles and facts. The exercises will give practice in applying chemical facts and principles to practical situations and in solving practical problems. They will also guide and help the students in studying and reviewing. The thirty-two unit tests are intended to serve as accomplishment tests to show the students and instructor the sections of chemistry that have been learned well. Direct page references are given to six well known text books in chemistry. Time varies, but each test can easily be completed in one class period.

Follett Publishing Company, 1255 So. Wabash Avenue, Chicago, Illinois. 25c Net. Transportation extra.

Selected Bibliography.

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GERMINATING SEEDS AND DEMONSTRATING ROOT HAIRS FOR CLASS USE.

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In this article is described a simple and efficient method by which seeds can be germinated in abundance for class use. The method has not only proven valuable for germinating seeds to show the early stages of seedling development but with a few modifications of the method excellent root hair demonstrations can be prepared. Complicated methods of seed disinfection are avoided and yet seedlings are obtained that are surprisingly free from microorganisms. The method is excellent for seed germination and the early seedling stages of growth, but if plants are to be grown to maturity, one should use other methods.

The seeds to be germinated were placed in a wide mouthed bottle that had a volume of from ten to twelve times that of the seeds. The bottle was then partially filled with tap water and the seeds allowed to soak. The length of time the seeds were soaked varied with the seeds from diffrent species of plants. After the soaking period the water was drained from the bottle and the seeds washed several times with fresh tap water. The mouth of the bottle was then covered with a glass plate and the bottle with the seeds was set aside to permit germination to occur. The bottle was usually set in an inverted position and the moist seeds either adhered to the side of the bottle or collected in the neck. Inversion of the bottle permitted better drainage of the water from the seeds and better germination usually resulted. After six or eight hours the seeds were again washed several times and the water drained off. This washing of the germinating seeds was repeated every six or eight hours until the seedlings had attained the desired size.

The length of the soaking period that has proven satisfactory and the time required for seed germination for the several varieties used are given in the following table. The seeds used were from some of the common varieties of cultivated plants. The seedlings of these several varieties of plants differ in their anatomical and physiological development. A column has been included in the table mentioning

the one or two characteristics in which seedlings of a given species excel. The time given is for the germination of the seedlings at room temperature (20-25°C).

Seeds used	Length of soaking period	Period of Germination from beginning of soaking period	Characteristics in which seedlings excel.
Wheat	4-6 Hrs.	2 days and longer	Rapid growth, root hairs.
Corn (Field)	6-8 Hrs.	3-4 days and longer	Adventitious roots, root hairs.
Barley	6-8 Hrs.	3-4 days and longer	Adventitious roots.
Oats	6-8 Hrs.	3-4 days and longer	Adventitious roots.
Cucumber	6-8 Hrs.	4 days and longer	Secondary roots, cotyledons.
Cabbage	6-8 Hrs.	4 days and longer	Root hairs.
Sunflower	6-8 Hrs.	3-4 days and longer	Cotyledons.
Buckwheat	6-8 Hrs.	3-4 days and longer	Primary root.
Garden Pea	6 Hrs.	4-5 days and longer	Plumule, primary root.
Radish	3-4 Hrs.	3-4 days and longer	Primary root, cotyledons.
Soy Beans	4-6 Hrs.	3-4 days and longer	

To set up a root hair demonstration six or eight seedlings were transferred from the bottle to a moist petri plate. Wheat was transferred when two days old and corn when three or four days old. The petri plate was then closed and kept in a moist chamber for a day. By the end of that period root hairs had usually developed. The closed petri plate facilitates the handling and observing of the roots and root hairs and at the same time protects the delicate root hairs from rapid desiccation.

By this method of seed germination a large quantity of seeds can be germinated with a minimum amount of time, effort and equipment. The various stages of seedling development can be readily obtained, for the developing seedlings are always visible. By germinating a relatively large number of seeds, one can supply the students with seedlings of uniform size. Dead seeds can be easily eliminated. The seedlings are free from soil or sand and broken seedlings, due to the removal of the seedlings from soil or sand plots, are avoided. The frequent washings of the seedlings make it unnecessary to employ complicated methods of seed disinfection so that one can supply the student with clean and well developed seedlings.

ICE AGE RHINOCEROS SKULL ADDED TO FIELD MUSEUM COLLECTION.

The skull of a rhinoceros that might well have been the target of Stone Age spears has been added to the exhibits in the Field Museum of Natural History here. The animal was a woolly rhinoceros, coeval in Europe with the great hairy mammoths and other beasts now extinct that roamed the valleys during later Ice Age times. The new specimen was sent by the Royal Museum of Brussels, Belgium.—*Science Service.*

CO-OPERATIVE MATHEMATICS HELPS INTRODUCE THE FORMULA.

By Fletcher Durell and Thomas J. Durell,

Belleplain, N. J.

To the beginner in the study of algebra, the topic which at first contact has the least appeal is the formula, and this in spite of the fact that it is the one which contains within itself the germs of the most comprehensive, fundamental. and far-reaching values.

For the formula is neither a picture like the graph, nor a story such as the verbal problem often is.

It is stark and bare without direct relation to the pupil's interest, or most of his past experience, and is not adapted to stimulate his imagination. The freedom from concrete entanglements which is a consequence of its bleak austerity, its statuesque aloofness, and which later is to prove so valuable, is apt to chill and repel the youthful mind at the outset.

This first lack of appeal is also usually increased by the fact that, largely from necessity, the applications of the formula as presented to the pupil at the beginning are so simple and childish as not to seem worth while, nor to justify the formation and study of this new instrument of technique. The examples ordinarily given at first can usually be more readily solved directly by the already known arithmetic, than by the mediation of this new machinery. Also the methods of solution used are so mechanical as to call for little or no self-activity or originality on the part of the pupil, and thus lack this method of arousing the pupil's interest.

The object of this paper is to make suggestions with a view to remedying this defect and also, if possible, to obtaining more positive advantages. We shall try to do this by treating the formula as a part of co-operative mathematics; that is, by causing arithmetical and geometrical concepts to throw light on the nature, uses, and values of the formula symbolism, and vice versa.

In order to make the discussion as clear and practical as possible, the proposed treatment will be presented in a form adapted to actual classroom use. Thus the presentation will consist of two parts: first, the explanatory, inductive ap-

proach, and, second, a set of practice examples to be worked by the pupil. These examples will be graded on the three level plan, so as to meet individual differences among pupils to some extent, or to suggest three stages of mastery by any pupil.

INTRODUCTORY STUDY.

(a) If one suit of clothes cost \$18 what is the cost of 30 suits?
The cost of 30 suits $=18\times30=\$540$.

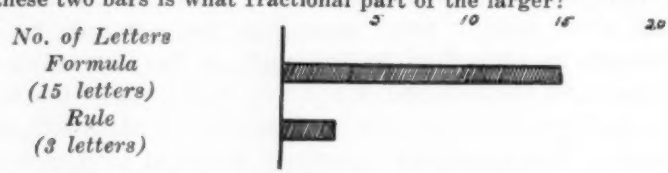
That is, the cost of all the suits equals the price of one suit multiplied by number of suits.

(b) So in general in buying articles of any kind we have the following short rule:
(Cost) = (price) $\times$ *(number)*
or more briefly $C=p\times n$, or $C=pn$.

(c) When a rule is shortened in this way by using a single letter instead of a whole word, the result is called a *formula*. What is the rule given above? What is the formula?

(d) If one pound of sugar costs 6 cents, what is the cost of 75 pounds? In this example state what is the value of *p?* Of *n?* Find the value of *c*.

(e) Count the number of letters in the rule given in (b). You will get 15. Also count the number of letters in the formula. You will get 3. Make a bar graph of the numbers 15 and 3. The smaller bar of these two bars is what fractional part of the larger?



LENGTH OF RULE AND FORMULA COMPARED.

(f) How far will an automobile traveling at the rate of 32 miles an hour go in 7 hours? We have distance $=32\times7=224$ miles.

So in general when we know the rate and time for a moving object we have the short rule:
(Distance) = (rate) $\times$ *(time)*, or
$d=r\times t$, or $d=rt$.

Give the rule in this case.
Give the formula.

PRACTICE IN USING FORMULAS.

I

1. If one barrel of apples cost \$2.50 what is the cost of 36 barrels? In this problem state the value of the letters, c, p, and n as used in the formula $c=np$.
2. If one baseball costs \$2.25 find the value of 8 baseballs. In this problem state the value of p, n, and c.
3. Find the value of c when $c=20\times3.75$. State this as a problem in finding the cost of 20 hats when the price of each hat is..................
4. If $p=\$1.25$, $n=18$, find the value of c. State this as a problem in finding the cost of 18 hammers, when each hammer costs..................
5. Copy the graph given in (e) above.

In this graph what is represented by the long bar? By the short bar? The larger bar is how many times as long as the shorter bar?

6. Count the number of letters in the rule *(distance) = (rate)* $\times$

(time). Also count the number of letters in the formula $d=rt$. Make a bar graph of these two numbers. In this graph what is represented by the longer bar? By the shorter bar?

7. In $d=rt$, find the value of d when $r=35$, and $t=6$. Also express this as a problem in finding the distance traveled by a railroad train which went for 6 hours at the rate of..................miles per hour.

8. In $d=r\times 8$ find the value of d when $r=4\frac{1}{2}$. Also express this as a problem in finding the distance traveled by a boy on a bicycle who went for 8 hours at the rate of......................miles an hour.

9. Count the number of letters in the words "United States." Also in U. S. Make a bar graph of these two numbers.

10. Count the number of letters in your full name. Also in your initials. Make a bar graph of these numbers.

II

11. In $c=np$ find the value of c when $p=.06\frac{1}{2}$ and $n=200$. Express this as a problem in finding the cost of a certain number of pounds of sugar.

12. In $d=rt$ find the value of d when $r=120$ and $t=3\frac{1}{2}$. Also state this as a problem in finding the distance traveled by an airplane in a certain number of hours.

13. In $d=rt$, find the value of d when $r=36$ and $t=2\frac{3}{4}$ and state this as a problem in finding the distance traveled by an automobile in a certain number of hours and minutes.

14. In $p=c\div n$ let $c=240$, $n=15$ and find the value of p. Express this as a problem in finding the price of one coat when 15 coats are bought.

15. In $p=c\div n$, find the value of p when $c=3.84$ and $n=12$. State this as a problem in finding the value of one pound of coffee.

16. Count the number of letters in the name of the state in which you live and also in the abbreviation most commonly used for this name. Make a bar graph of these two numbers.

III

17. In $r=d/t$, let $d=65$, $t=2\frac{1}{2}$ and find r. State this as a problem in finding the rate per hour at which an automobile traveled.

18. In $c=pn$, find the value of c when $n=9$ and $c=.32$. State this as a problem in making some purchase at a grocery store.

19. In $p=c\div n$, find the value of p when $c=264$ and $n=12$. State this as a problem in finding the cost of a number of dresses.

20. By substituting for each letter the word it stands for, state the formula $p=c/n$ as a rule.

21. Express $n=\frac{c}{p}$ in words as a rule. Make up some problems to be solved by this rule.

22. Express the formula $t=\frac{d}{r}$ in words as a rule. Also $r=\frac{d}{t}$ as a rule.

23. We have three rules (see problems 18, 20, 21) expressed by the formula $p=br$, or by 3 letters. Count the total number of letters in the three rules taken together. Make a bar graph to show the value in the formula $p=br$ with respect to its economy in the use of letters.

24. What do the letters C. O. D. stand for as these letters are commonly used in business? Make a bar graph for the number of letters in this abbreviation and in the phrase for which it stands.

25. Select two other abbreviations in general use and treat them in like manner.

A similar co-operative method may be used in studying formulas in connection with other topics. Thus for the formula for percentage we have the following:

Approach to the Percentage Formula.

(a) To get a short rule and a formula as a help in solving examples in percentage, let us start with the following easy examples:

Find 6% of 250.

We have percentage $= 250 \times .06 = 15$

In such an example, the 250 (that is, the number a per cent of which is found, is often called the *base*, and the .06 the *rate*.

Hence we have the following brief rule:

(percentage) $=$ *(base)* $\times$ *(rate)*

or more briefly $p = b \times r$

or shorter yet $p = br$.

(b) Find 5% of \$240. In this example give the value of b, of r, of p.

(c) In $p = br$ find the value of p when $b = 150$ and $r = .06$. Express this as a problem concerning a woman who had 150 chickens and sold..............................per cent of them.

Practice in Using the Percentage Formula.

1. Find 8 per cent of 450. State the value of *b* in this example, of *r*, of *p*.
2. In $p = br$, find the value of p when $b = 180$ and $r = .45$. Express this example as a problem in finding the number of boys in a school containing 180 pupils of whom..........................per cent were boys.
3. In $p = br$ find the value of p, when $b = \$2400$, and $r = .15$. Express this in a problem concerning a man who received....................per cent increase in his salary of.........................
4. In $p = br$, find p when $b = 80$ and $r = .75$, and express this as a problem concerning a boy who spelled correctly......................per cent of the 80 words in a spelling test.
5. Count the number of letters in the rule for percentage given in (a) above. Also count the number of letters in the formula. Make a bar graph of these two numbers. In this graph, the larger bar is how many times as long as the shorter one?

II

6. Find p when $b = 48$ and $n = .66\ 2/3$. Express this as a problem in finding the number of games won by a team.
7. Find p when $b = \$4500$ and $r = .02\frac{1}{2}$. Express this as a problem in finding the tax on a property valued at..............................

III

8. Express $r = \frac{p}{b}$ in words as a rule.
9. In $r = \frac{p}{b}$, let $p = 72$, $b = 80$, and find r. Express this as a problem concerning a spelling test in which the number of words was 80.
10. Express $b = p \div r$ in words as a rule.

It is evident that this same general method can be used in studying the formula for interest, $i = prt$; for the area of a rectangle, $A = lw$; and so on.

Advantages of the Co-operative Method.

As previously indicated, the above is called the co-operative method of studying a principle because by it a many-sided light is thrown on the subject in hand by a combination of the three essentially distinct mathematical dis-

ciplines, arithmetic, algebra, and geometry. The geometric or pictorial element in the above treatment of the formula is, of course, supplied by the graphs given or called for. The arithmetical part occurs not only in the numerical problems, but also in quite as important a way in the counting of the numbers of letters in the different rules and formulas and in finding the ratios or fractions called for with respect to these numbers. The role of algebra is emphasized by the transformations of the formula asked for in some of the examples. Thus the three main, elementary branches of mathematics actively help and mutually reinforce each other in the given situation, which is both a difficulty and an opportunity.

It is also to be noted that this method calls into action and has an appeal and a value for each of the leading mental processes, viz: cognition or learning new knowledge, feeling or appreciation of the value of such knowledge, and action. Thus it gives a many-sided understanding of the instrument being studied, a similar varied appreciation of its worthwhileness, and an enlistment of the self-activity of the pupil by progressive steps in several different directions.

This method can be used alike at the first introduction of the formula whether in the study of arithmetic in Junior High School Mathematics, or in the study of algebra as a separate and distinct discipline in a Senior High School Curriculum.

When the formula has thus been grasped as a familiar friend, it is easier and more natural to go on and study its higher uses and more comprehensive and fundamental powers. These more advanced developments will then more naturally take a shape whereby the formula is a part of cooperative mathematics all along the line.

This development is illustrated in what we may term the formula-equation. An example of the use of this is the construction of the family of curves or graphs represented, for instance, by $y=ax^2$ when we let $a=1, 2, 3$, etc., $\frac{1}{2}$, $\frac{1}{4}$, etc., in turn.

Another case is the solution of all the verbal examples of a given type by first solving a problem of this type in which all of the given quantities are in the literal form and thus

getting the values of the unknowns in the shape of formulas in which any particular set of ordinary numbers can be substituted. A simple example of this kind is:

Find two numbers whose sum is a, and difference is b.

The method of introducing the formula which is being advocated in this article also makes it easier and more natural to gain a full grasp of the principle of functionality, variation, or dependence, which many regard as the root idea of all algebra, and which is certainly one of the most fundamental and comprehensive principles in mathematics as a whole.

It remains to mention in this connection one other value which perhaps is more important than any values thus far stated. This is the deep and radical organizing and simplifying power which characterizes the formula when its use is fully developed. This power is glimpsed or indicated in an initial way in the last three examples in the above practice exercise on percentage. In these problems, the original formula and rule, and the two derived formulas $r=b\div p$ and $b=p\div r$ and the rules corresponding to them are seen to be simply different aspects of one principle. Thus it is made evident that it is not necessary to study and master each of these by itself as a separate topic. On the contrary they are revealed as so intimately related that they can be comprehended, so to speak, at one stroke.

Avoiding a Danger.

So great are the values inherent in the formula and capable of being developed from it, that, after one has learned to appreciate these, there is a danger that one may go too far and in some cases and ways come to overuse this instrument. Thus a certain reproach sometimes comes to be attached to the word formula as when we say of some man, even highly cultured perhaps, that he has reduced life to a formula, meaning by this that he has reduced his life to a single idea, carried out mechanically.

Napoleon had a high appreciation of distinguished men of science and often tried to utilize them in the service of the state. Thus at one time he appointed the great French mathematician Laplace as one of his ministers. But after a trial he later removed Laplace from this public post saying that he seemed to require a formula for every detail

of his work. In other words the great mathematician had become so formula-minded that his faculties were no longer flexible and resourceful with respect to the multitudinous emergencies of a rapidly shifting practical life.

An early study of the formula in the co-operative way, a free grasp of its spirit apart from, yet along with a knowledge of its mechanical technique should go far to keep one clear from the pitfall which has just been described.

IN CONCLUSION.

The formula when developed in its full power, becomes the queen among algebraic topics, but, if rightly understood and used, a democratic queen, ruling and dominating only when such a position is justified by a superior capacity for service. This position is best obtained and maintained if at the outset and all along the line the formula is used in free and active co-operation with other instruments.

FIREWORKS FROM A "FERN."

It has long been a matter of general knowledge to the writer that Lycopodium spores can be used as fireworks material, but it is only recently that an actual test of this fact has been made in the field. Very possibly it is familiar to many readers of the Fern Journal, but on the chance that there may be others who have not tried it, this note is published.

On a recent trip near Greenwood Lake, N. Y., colonies of fruiting Lycopodiums *(L. obscurum, L. complanatum, L. clavatum)*, were found near Cedar Pond, one of the northern localities for the southern white cedar. The fruiting spikes were in a condition to discharge their spores at a slight touch. When a burning match was held in readiness the spores ignited with a little puff.

Later, in the city, an ounce of *Lycopodium* spores was purchased at a drug store and the material was used for an entertainment demonstration at the start of a general science class period. Apparently a definite condition of suspension in the air is necessary for the flashing effect. When a match was held to a small quantity of the spore powder on a stone window ledge, nothing happened; when a small quantity of the powder was placed on a thin copper plate and heated over a Bunsen burner the spores scorched and blackened but did not flash. When, however, a pinch was dropped into the flame of a burning match, an instant pyrotechnic display was obtained.

The material was of special interest to the chemistry teacher of the department as being more suitable for demonstrations of the explosive quality of dust than the ordinary substances used in this connection. Any one interested to try it is cautioned against using too much at a time. It seems entirely likely that a dangerous explosion might be produced if a considerable quantity were released in the air of a room.—*American Fern Journal.*

IN WHICH DIRECTION DOES AN ELECTRIC CURRENT FLOW?

By L. E. McAllister, Ph.D.,
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Many teachers of elementary physics in high school and college have been asked by students why some one does not straighten out the inconsistency now existing between the direction of flow of electric current and the flow of electrons that make up that current. They can be answered by saying that the direction of the current was arbitrarily defined, unfortunately in the wrong direction, before the electron was known to exist; and that scientists have not made sufficient effort to correct the error. Many students are not satisfied with such an answer, but insist that some one ought to try to correct such an inconsistency.

A common suggestion is to consider the direction of the electric current the same as that of the electrons, i. e., from the negative to the positive terminal of a battery in an outside circuit. There is no doubt that the electrons are what actually travel in a wire and that the current ought to be considered in the direction of their flow. However, if that were the only change made it would be very difficult to teach the common rules of electricity for most of them would have to be changed from the use of the right hand to the left hand and vice versa. That would be very confusing to both teachers and students unless all texts and reference books on the subject were immediately rewritten to conform to the change. This would be practically impossible.

The proposal the writer wishes to submit for discussion and criticism among physicists and teachers is as follows: Consider the direction of the current to be the same as that of the electrons *and at the same time consider the direction of a magnetic field to be that in which a free south pole would move.* These two changes compensate each other when we are considering the common laws and rules for remembering electromagnetic phenomena.

Consider some cases: Case I. We say that if we grasp a wire with the right hand in such a way that the thumb points in the direction of the current, the fingers will go around in the direction of the magnetic field. If we change the sense of the direction of the current and not the mag-

netic field, the left hand would have to be used. Also a left-handed screw motion, which is uncommon and unnatural, would have to be used to illustrate the case. If we look at both the current and the magnetic field in the other direction the rule will be unchanged and students would have very little difficulty in going from a new to an old book or vice versa.

Case II. The rule for finding the direction of the magnetic field through a coil of wire would work the same way as this one, i. e. if one grasps a coil of wire with the right hand so that the fingers go around in the same direction as the current is flowing in the wire, the thumb will point in the direction of the lines of magnetic force through the coil. That is the conventional way of looking at it. Now if the sense of the direction of only the current is changed, the left hand must be used; but if the sense of both current and magnetic field are changed, the rule holds just the same as before. A point that would have to be remembered would be that now the thumb would point toward the south pole of the coil instead of the north, for under the new scheme the lines would go from north to south inside and south to north outside.

Case III. When one applies Lenz's law to the different cases usually found in an elementary text-book it makes no difference what scheme is used so long as it is followed consistently.

Case IV. Fleming's right- and left-hand rules for the generator and motor. The right-hand-generator rule is as follows: With the thumb, first finger, and middle finger mutually perpendicular to each other, point the thumb in the direction of motion of the wire, the first finger in the direction of the magnetic lines and then the middle finger will point in the direction of the induced current. If only the sense of the current is changed the left hand would have to be used and every one who has learned this rule would be confused at least for a while. If the sense of direction of both the current and magnetic field were changed the rule would not be changed and no confusion would result in going from the old scheme to the new and vice versa. The same thing holds exactly for the so-called left-hand-motor rule.

In advanced theoretical physics this proposed change would make it necessary to change some signs in existing equations where either the magnetic field or the current alone is being considered. In many cases where minus signs have to be carried through a derivation, the change would simplify matters. In others, complications would arise till we got used to it, but those cases would be faced by more advanced students who would be able to reason correctly, regardless of convention of signs.

WHERE SHALL THE EMPHASIS BE PLACED?

G. T. FRANKLIN, *Lane Technical High School, Chicago*

Has it ever occurred to you that when a sturdy is made of a simple voltaic cell using dilute sulfuric acid, copper, and zinc, that the formation of hydrogen on the positive plate and then the study of a simple electrolysis experiment in which hydrogen is deposited on the negative plate, may seem inconsistent to some beginners? Of course the ordinary galvanic cell and the electrolytic cell are just opposites in many respects; the former has current flowing from positive to negative in the external circuit, while the latter has current from positive to negative in the internal circuit. One generates electricity, the other uses it. However, in either case hydrogen is formed by the discharge of hydrogen ions, which means electrons must come from some source. There is no oppositeness in this respect. It seems to me that the beginner ought to be ready to receive the information that when hydrogen or any other substance forms on the surface of a metal in the course of a reaction, that the continuance of the reaction means the removal of the surface coating as fast as it is formed and that some metals release hydrogen from their surfaces much more readily than others. It seems to me that, while the formation of a hydrogen coating on zinc is invisible, yet its explanation ought to be within the comprehension of the beginner as well as many other examples of a like nature that we attempt to teach. The problem is abundantly demonstrated by experiments in beginning courses. Generally if pure zinc is not at hand and it is difficult to get, a subterfuge is used by alloying impure zinc with mercury, so that an electrode of mercury-zinc-impurity is obtained, which does not react with acid by itself. If the plate is immersed in acid and a copper wire is made to touch it, abundance of hydrogen comes from the surface of the copper. If platinum is used, the formation of hydrogen is greater. If the copper is connected to the alloy through an external circuit of considerable resistance, some hydrogen is obtained in spite of the larger amount of work required to transfer the electrons from the zinc through a resistance. It is evident from such experiments that it requires less work to transfer electrons through considerable resistance than it does to remove hydrogen from the surface of zinc amalgam.

Explanations of this kind not only have the advantage of being more nearly correct from a scientific point of view, but lay the foundation for future studies of catalysis, a matter of great import.

THE PART PLAYED BY ASSUMPTIONS IN MATHEMATICS AND PHYSICS.

By P. H. NYGAARD,
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Through the application of mathematics there has been built up a complicated system of laws to explain the observed facts of physics. Since the beginning of the present century we have had the electron theory of the atom as originated by Rutherford and Bohr, the quantum theory of the emission of energy whose development started with Planck, and the relativity theory of Einstein. These and other associated theories have met with remarkable success in agreeing with experimental data. Predictions based on this new mathematical physics are verified with startling accuracy.

There are, however, good reasons for not believing that these theories give a true picture of the world that surrounds us. In spite of the elaborate use of mathematical analysis and the extensive array of experimental verification to which their proponents may point, there is still ample room for doubt as to their ultimate truth. In this paper an effort will be made to justify such skepticism by showing that the laws of mathematics and physics are based largely on arbitrary assumptions.

I. ASSUMPTIONS IN MATHEMATICS.

Since all the modern theories of physics are entirely mathematical, it will be advisable to consider first the extent to which assumptions enter into mathematics. It is impossible to prove deductively that any of the laws of mathematics agree with empirical facts. All that it is possible to prove is that these laws agree with certain assumptions that were made at the outset. If the assumptions had been different, the resulting laws would also have been different.

The simplest illustration of this is the geometric postulate that through a given point only one parallel can be drawn to a given line. From this assumption it follows by deductive proof that the sum of the angles of any plane triangle equals 180 degrees, which is one of the fundamental theorems of Euclidean geometry. Mathematicians after Euclid were reluctant to accept this postulate as an assumption, but they tried in vain to prove its truth. In 1826

Lobatschewsky[1] denied this postulate altogether, substituting for it the assumption that through a given point *any number* of straight lines can be drawn parallel to a given straight line. On the basis of this postulate he developed a complete geometry, one of whose theorems is that the sum of the angles of any plane triangle is always less than 180 degrees, but as the triangle becomes smaller the deficiency approaches O as a limit. Thus for small triangles his geometry approximates that of Euclid. Later Rieman postulated that through a given point *no* straight line can be drawn parallel to a given straight line, and he too was able to work out a geometry coherent with this assumption. In Rieman's geometry however the sum of the angles of any plane triangle always exceeds 180 degrees, but as the triangle becomes smaller the excess approaches O as a limit. Thus for small triangles his geometry also approximates that of Euclid. It is not possible to prove that either of these non-Euclidean geometries is false. Rieman's viewpoint, not Euclid's, is the one adopted by Einstein in his theory of relativity.

Nearly all the basic assumptions of Euclidean geometry are being questioned. We are no longer sure that a straight line is the shortest line between two points, nor that space is three-dimensional. These assumptions are being discarded, but the important thing to remember is that their place is being taken by other hypotheses which are just as much assumptions as the ones that are being abandoned. That the mathematics of spatial relations is dependent so largely upon assumption should give us much concern, for it is this branch of mathematics alone which connects the abstract with the concrete.

The dependence of mathematics upon assumption shows up not only in geometry but also in the mathematics of number relations. The commutative, associative, and distributive laws, which furnish the basis for all algebra and arithmetic, may seem fairly self evident when used in operating with integers, because we can then attain some sort of verification by means of counting. These laws however are assumed to be equally true when dealing with fractions,

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[1]A good introduction to non-Euclidean geometry may be found in "Non-Euclidean Geometry" by W. H. Bussey, The Mathematics Teacher, December, 1922.

negative numbers, irrationals, and imaginaries, for which direct verification by counting is inapplicable. These latter assumptions are purely arbitrary conveniences justifiable solely by analogy to integers. A mathematician does not usually openly admit that the fractional, negative, irrational, and imaginary numbers are simply fabrications invented or assumed to enable him to perform otherwise impossible operations, but this they certainly are.[2] Besides these numbers we have in modern mathematics the concepts of the infinite and the infinitesimal, both of which concepts arise through assumed definitions, but which are, nevertheless, the foundation stones of the most far reaching branch of mathematics, the calculus. Nearly all the laws of mathematical physics are stated in the form of differential equations, and since such equations are a part of the calculus, the conclusion can not be avoided that these laws depend upon the assumed definitions of the infinite and the infinitesimal.

II. Assumptions in Physics.

In order to appreciate the part played by assumptions in physics it is perhaps best to start with a survey of the various theories of the constitution of matter.[3] The first modern theory was based on the molecule as the smallest particle of matter. This satisfied all requirements for a time, but certain experimental facts were later noticed which could not be explained by the molecular theory. This led to a new assumption, the atom. The atomic theory served very well, especially in the field of chemistry. However it was not long before it too became insufficient. But the scientist was not balked very long. All he had to do was to make a new assumption, that each atom is composed of still smaller particles called electrons and protons. This is Bohr's theory of the atom, which can be briefly stated as follows: Matter is composed of two kinds of particles, electrons and protons, having equal but opposite charges of electricity; any unelectrified atom consists of a number of electrons revolving in circular orbits about a nucleus, the number of these revolving electrons being exactly equal

[2]For a clear-cut explanation of how these numbers have arisen see "Engineering Mathmatics" by Charles P. Steinmetz.

[3]"The Analysis of Matter" by Bertrand Russell contains a thorough discussion of these and other modern theories of physics.

to the atomic number of the element in the periodic table, while the nucleus contains as many protons as the atomic weight of the element and as many electrons as the difference between the atomic weight and the atomic number; a revolving electron does not always stay in the same orbit but at times jumps to orbits of different radius; if the electron changes to a smaller orbit a certain amount of energy is lost, it is supposed that this energy is radiated out in the form of a light wave, and the amount of this energy is supposed to be the same as Planck's quantum. Small discrepancies were soon found between this theory and certain delicate facts. These were obviated by assuming that the revolving electron could have an elliptical orbit rather than just circular and that the plane of the electron's orbit could have various inclinations. Heisenberg, realizing that all these assumptions were only an effort to make a model of the atom which could be visualized by the human mind and that they were all based on nothing more than analogy to the theory of the solar system, has recently set forth a theory that denies any real existence to the electrons and protons. In his theory the atom remains an abstract entity whose properties can be represented only mathematically, and then not without assuming a new algebra of matrices in which the commutative law for multiplication is not true, that is in which p times q does not equal q times p. The only thing we are likely to be sure of after reading the above is that if any further unexplained facts arise there will be speedily found a suitable assumption whose acceptance will again make everything easy to understand.

Similar conditions are found in regard to the theory of relativity. The fundamental assumption upon which everything in the general relativity theory depends is a differential equation for $(ds)^2$, in which s represents the interval between two events in a four-dimensional co-ordinate system. This equation is based on analogy to the Pythagorean theorem. If s represents the distance between two points on a plane having co-ordinates x and y, the Pythagorean theorem gives the differential equation, $(ds)^2 = (dx)^2 + (dy)^2$. If s represents the distance between two points in three-dimensional space using co-ordinates x, y, and z, there re-

sults the differential equation, $(ds)^2=(dx)^2+(dy)^2+(dz)^2$, also by the Pythagorean theorem. Einstein has extended this method, with modifications, to finding the interval, which is a combination of distance and time, between two events in four-dimensional space. The theory of relativity denies the exact truth of the Pythagorean theorem in space of two or three dimensions, but is itself based on an assumed analogy to that theorem in space of four dimensions.[4]

The whole process by which these theories have been devised may be summarized by saying that whenever there has been discovered a fact, or group of facts, which does not agree with then existing theories, a new assumption has been invented to explain it. A similar process occurs in algebra. If one unknown is to be found, only one equation is needed. To find an additional unknown a second equation is needed, and so on indefinitely. Each new unknown quantity requires the addition of a new equation, just as each new unexplained fact in physics needs for its explanation a new assumption.

Are not, you may want to ask, the theories of physics sufficiently proved by the fact that they work? No, not at all. Even though it be admitted for the sake of argument that these theories are in the main correct, there is nevertheless strong probability that they do not expose ultimate truths. They may state nothing but the truth, and still not state the whole truth. This distinction is illustrated by Kepler's three laws to explain the motions of the planets. His laws agreed with all the observed facts, but in spite of this they were soon superseded by Newton's law of gravitation. The law of gravitation contains Kepler's laws as special cases, but it also explains many phenomena for which Kepler's laws are inapplicable. Hence Newton's law was accepted as the ultimate truth. The illustration can, of course, be carried further, for now the general theory of relativity is accepted as a simpler and more fundamental theory than Newton's, although Newton's law continues to be true as a special case under the new theory. Whether the theory of relativity is the ultimate truth we do not know, but the presumption would be that it is not.

[4]"Analysis of Matter" by Bertrand Russell, page 61.

A further illustration will be given to show that modern physics may not be fundamentally true. Consider the relationship between the number of inches, the number of feet, and the number of yards in a certain length. Many different formulas can be used to show how the number of yards depends upon the other two. One person might say that the number of yards can be found by adding the number of inches in the length to the number of feet in the length and dividing the sum by 39. That is, $y=\frac{i+f}{39}$. Thus if $i=72$, $f=6$, and $y=\frac{72+6}{39}=2$, which is the correct value in terms of yards. A second measurer of lengths might say that $y=\frac{5i-7f}{159}$. Another might claim that f has nothing to do with it, and say that $y=\frac{i-2}{12}-\frac{i}{18}+\frac{1}{6}$. If a fourth measurer should decide to apply more advanced mathematics, he might state that $y=\sqrt{\frac{5i^2-2if-7f^2}{6201}}$. All four of these formulas are correct from the standpoint that they agree with observed facts. However you would not wish to accept any of them as a true statement of the relationship involved. You would say that the really true formulas are $y=\frac{f}{3}$ and $y=\frac{i}{36}$. Similarly, the physicists, in trying to measure the properties of matter, may have theories that agree with experimental data and still be far from basic truths.

There are strong reasons for going so far as to believe that these theories do not contain any real truth. They may be false and still seem successful in agreeing with experimental data. Eddington is quite outspoken in his support of this view. He says: "Something unknown is doing we don't know what—that is what our theory amounts to."[5] The experiments of physics have long since gone by the stage when results were based directly on what was seen

[5] "The Nature of the Physical World" by A. S. Eddington, p. 291. Throughout this book by one of the most eminent scientists of our time are scattered statements of similar import. For instance, on p. 219 he designates Schrödinger's wave mechanics as "not a physical theory but a dodge" based on a kind of space "imagined by the mathematician for the purpose of solving his problems." On pp. 260 to 262 he explains how the modern physicist by following his laws is only going around in an endless circle and getting nowhere.

or heard or felt by the experimenter's senses. Nearly all modern results are tied up with measurements of light and electricity. The theories advanced in explanation of light and electricity are particularly unstable, and are, of course, based on assumption. Experimental results involving light and electricity must therefore necessarily be tainted by the fact that they are obtained and interpreted through the agency of theories which are themselves insecure. One of the simplest tasks of the experimenter would seem to be the measurement of a length. But according to the theory of relativity the length of an object depends upon its velocity, and there are no stationary objects. Delicate measurements of length may be based on light waves, which immediately bring in the much disputed wave theory of light. And then non-Euclidean geometry states that a straight line may not be the shortest line between two points. Hence even such a relatively simple process as the measurement of a length cannot be disassociated from a maze of theory. All that such experimenting proves is that the results obtained agree with the assumptions, not that they agree with reality.

III. What are We to Believe?

It will perhaps be safest to let the reader draw his own conclusions as to the validity of the laws of mathematical physics. Several possible beliefs will be outlined.

A conclusion which might be satisfying is that these laws are at best only fragmentary expositions of underlying facts. Our theories and even our measurements may be sadly incomplete. Heisenberg in 1927 set forth a principle of indeterminacy (or inexactitude) which conforms to this view.[a] According to this principle it is impossible to know exactly both the velocity and the location of any particle; accurate determinations can be made of certain properties only at the sacrifice of accuracy in regard to others; physicists are doomed to a knowledge of half-truths. The laws of mathematical physics may represent only mountain peaks projecting above the clouds, but giving little indication of the nature of what lies beneath.

Another possible conclusion is that there are no causal

[a]See "The Nature of the Physical World" by Eddington, p. 220 and p. 306. Also "Critique of Physics" by L. L. Whyte, p. 74 and p. 190.

laws behind the observed facts of science—in other words that events just happen by chance and that the laws involved are simply those of probability. Quantum theories are based on such chance occurrences, for these theories contain no explanation of when or why an atom "chooses" to jump from one state to another. The jumping back and forth is left to chance. Suppose in a certain atom the chances are 4 to 1 that it will jump to state A rather than to state B. It is impossible to predict with any certainty which change will occur in a single atom, but if 1,000,000 atoms are grouped the prediction can be safely made that the result for the whole group will be predominantly a change to state A. While that prediction is not absolutely certain, the probability of its failure is only 1 out of a number so large that if it were written out in the usual method it would occupy about 9 printed pages. Again, if there is only 1 molecule in a closed container, there is no law that can predict in which half of the container it will be at a certain time. If there are 1,000,000 molecules in the container, we can predict that they will be found scattered quite uniformly throughout the container. This prediction is not based on a causal law, but is simply the result of the combined chance movements of all the molecules. There is, of course, a possibility that all the molecules will be found in, say, the right half of the container, but this possibility is dismissed as being too improbable. Although the number of years of life that is left for me is highly uncertain, it does not therefore follow that life insurance companies are risky enterprises. On the other hand, they are among the most stable of all forms of business, because the average life expectancy of a large number of men of my age is predictable within narrow limits. Modern physics succeeds in predicting only those events whose occurrence depends upon the combined probabilities of numerous independent items. Its laws have therefore been called by Eddington and others statistical rather than causal.

A third possible belief is that these theories have not in any sense succeeded in erecting a structure of matter, but have instead erected a structure of the mind. It must be admitted that nothing has as much reality to us as our own consciousness, our own awareness of having a mind.

The existence of every other thing has to be accepted with varying degrees of reliability, because we know of them only through intermediary processes such as sense perceptions, inferences, and the testimony of others. The physicist has focussed his attention upon matter; mind has seemingly been left out of the picture. Attempts have even been made, by breaking up mental processes into electrical circuits, chemical actions, and the like, to show that these processes obey the same laws as matter. In short, physicists of this school would have you believe that mind is made up of matter. However it may very well be that Eddington is right in saying that "the stuff of the world is mind-stuff."[7] That view has the distinct advantage of building upon a foundation that is the closest known approach to reality, our own mental consciousness, instead of building upon relatively unknown concepts of matter. Paradoxical as it may seem, perhaps that is exactly what the physicist has unwittingly done. He has not kept mentality focussed out of the picture. How could he expect to keep it out? Light is needed in order to take a picture. Mind is the light that actuates the camera of the physicist. A picture taken with too much exposure to light shows on the negative only blotches of light. So much mentality has been utilized in the making of the physicist's picture that there is revealed on the picture only that mentality. This view is beautifully expressed by Tobias Dantzig in the following words: Whenever the man of science "discovers a law of striking simplicity or one of sweeping universality or one which points to a perfect harmony in the cosmos, he will be wise to wonder what rôle his mind has played in the discovery, and whether the beautiful image he sees in the pool of eternity reveals the nature of this eternity, or is but a reflection of his own mind.'"[8]

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[7] "The Nature of the Physical World," p. 276.
[8] "Number the Language of Science" by Tobias Dantzig, p. 230.

BIG ALL-AMERICAN TELESCOPE MIRROR UNDERGOING TESTS.

The biggest telescope mirror ever to be made entirely in the United States, 69 inches from rim to rim of its concave face, is now undergoing its final tests at the factory of the J. W. Fecker Company at Pittsburgh. If it passes them successfully it will soon be on its way to Delaware, Ohio, to be mounted at the Perkins Observatory of Ohio Wesleyan University.—*Science Service.*

PROBLEM DEPARTMENT.

CONDUCTED BY G. H. JAMISON,
State Teachers College, Kirksville, Mo.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to G. H. Jamison, State Teachers College, Kirksville, Missouri.

SOLUTIONS OF PROBLEMS.

Editor.—Persons sending in solutions should read carefully the instructions about the form of the solutions and the ink-drawn figures. Many times, a good solution is received, but poorly arranged and no India-ink figure given.

1181. *Proposed by George Sergent, Tampico, Mexico.*

Four numbers are in geometrical progression; their sum is 50, and the sum of their squares is 5125. Find the numbers.

Solved by B. M. Lindemuth, Defiance, Ohio.

(1) Let a, ar, ar^2 and ar^3 represent the numbers.
(2) Then $a+ar+ar^2+ar^3=50$
(3) And $a^2+a^2r^2+a^2r^4+a^2r^6=5125$
(4) $a(1+r)\ (1+r^2)=50$ Factoring (2)
(5) $a^2(1+r^2)\ (1+r^4)=5125$ Factoring (3)
(6) $a=\dfrac{102.5(1+r)}{1+r^4}$ Dividing (4) and (5) and solving for a
(7) $52.5\,r^4+205\,r^3+205\,r^2+205\,r+52.5=0$ Substituting for a in (2)
(8) $5(3r^2+10r+3)\ (3.5r^2+2r+3.5)=0$ Factoring (7)
(9) If $3.5r^2+2r+3.5=0$, r is imaginary
(10) If $3r^2+10r+3=0$, $r=-3$ and $-\frac{1}{3}$.
(11) When $r=-3$, $a=-2.5$ Substituting in (6)
(12) When $r=-\frac{1}{3}$, $a=67.5$ Substituting in (6)
(13) $\therefore$ the numbers are -2.5, 7.5, -22.5 and 67.5 in this or the reverse order.

Also *solved by Lester Dawson, Wichita, Kansas; W. E. Batzler, Battle Creek, Michigan;* and *Melvin Dresher, Hackensack, N.J.*

1182-1186. No solutions were received for these problems. Upon receipt of solutions, they will be printed.

PROBLEMS FOR SOLUTION.

1199. *Proposed by O. T. Snodgrass, Columbia, Mo.*

For the equation $x^y=y^x$, find $\dfrac{dy}{dx}$ to be $\dfrac{y^2(\log x-1)}{x^2(\log y-1)}$

1200. *Proposed by R. T. McGregor, Elk Grove, California.*

Evaluate $\left(\dfrac{\tan x}{x}\right)^{\frac{1}{x^2}}$, when $x=0$

1201. *Proposed by Lester Dawson, Wichita, Kansas.*

Factor $(x+y)^5+(x+z)^5+(y+z)^5$.

1202. *Proposed by Clyde Bridger, Walla Walla, Washington.*

Find the magnitude of a trihedral angle of a regular tetrahedron. See problem 1133.

1203. *Proposed by Nathan Altshiller-Court, Norman, Oklahoma.*

The common perpendicular of two opposite edges of a tetrahedron is perpendicular to the lines joining the mid-points of the other two pairs of opposite edges of the tetrahedron.

1204. *Proposed by a Student, Eldon, Missouri.*

Solve for x and y the pair of equations

$$\frac{x^2+y^2}{2x}=a$$

$$\frac{x^2+y^2}{2y}=b$$

A PROPOSITION TO HIGH SCHOOL CLASSES IN MATHEMATICS.

The Editor of this department would like to see to what extent classes in mathematics in high schools are studying problems submitted for solution. Already a few suggestions have come, and as a result a few problems of a type suitable for high school classes will be proposed. Of course the larger number proposed will be for those beyond high school level. The Editor proposes to make honorable mention of those high schools which make noteworthy contribution as a result of class or group discussion of problems proposed. The teachers are urged to write the Editor, stating the extent to which high school classes or groups consider the problems. For example, the Mathematics Club of the Senior Gratz High School, Philadelphia, reported that it discussed problem No. 1171 and arrived at no solution. When the solution was published, the Club studied it and found the statement, that $OB=OC$, is an error.

The Editor will be pleased to make special mention as below if teachers will report to him.

HONORABLE MENTION

For High School Classes or Groups Making Contribution to This Department

Senior Gratz High School, Philadelphia. Problem 1171.

SCIENCE QUESTIONS

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

WHAT IS PHYSICS?

"Physics, someone has said, is the Aaron's rod that is swallowing up all the other sciences. A survey of recent trends suggests that something of the kind is taking place. Certainly many of the specialized sciences are drawing increasingly upon physics to explore and explain their phenomena, and to that degree they are becoming departments of physics. Chemistry, in its fundamentals, has become *physical* chemistry—and it would take a clever balancer of fine points to say where physics leaves off and chemistry begins. Astrophysics is now the main concern of astronomers. Geophysics is more and more encroaching upon the preserves of the geologist. Oceanographers are finding in the physics of the sea a new approach to problems formerly regarded as biological. And biologists, peering into the living mystery of protoplasm, are asking whether its processes, too, may not be resolved into the ultrascopic mechanics of electrified particles, excited ions, speeding electrons—the action of forces wholly physical."

The above is the first paragraph of an article in the November, 1931, issue of THE ATLANTIC MONTHLY entitled "*Measuring the Divine Spark,*" by George W. Gray.

The entire article is full of *Science Questions—Why do we grow old? Why do we die? Why do we live? Why does a living cell divide? What is the influence of electricity upon living cells?*

Did you know that "the apex of a living thing is electropositive"?

Did you know that "the electromotive force of a Douglas fir registered as high as one-tenth of a volt in a ten-year-old tree"?

How does a living thing generate electricity?

WHAT TO READ.

589. *What articles have you read that the science teacher or the pupils should read?* Please send the titles to the *Editor*.

WANTED: A TEST IN PHYSIOGRAPHY.

590. "I would like you to send a copy of Test Questions on Physiography," John Koors, Jr., 1733 Brown St., Dayton, Ohio. (Please send to the *Editor.)*

591. *Proposed by Sudler Bamberger, Harrisburg, Pa.*

A sphere of sp. gr. 6/10 and diameter 3 ft. is dropped into a lake of 20 ft. depth. How high above the lake must it be dropped to just descend to the bottom?

EXAMINATION PAPERS.

Please send copies of any recent examinations or tests to the *Editor*. Other teachers are interested.

The following examination papers were submitted by Wm. F. Rice, Head Science Dept., Jamaica Plain, Mass.

Jamaica Plain High School, February 17, 1931.

Biology

Write the number of this paper at the top of your answer paper. Do not mark on this question paper. Make drawings of good size and label them neatly. Answer any eight (8) of the following ten questions.

1. Draw a diagram of a typical flower; labeling each part.
2. Make a labeled drawing of a cross-section of a leaf.
3. Give the use of each of the following tissues: in a stem: (a) epidermis, (b) cambium, (c) ducts, (d) pith, (e) pith ray, (f) wood fiber.
4. Make a labeled drawing of a cross-section of a monocot stem.
5. Draw a root hair and show how it fulfills the conditions for osmosis.
6. Make a labeled drawing of a spirogyra.
7. Write a brief note on each of the following topics in connection with bacteria: (a) forms, (b) reproduction, (c) conditions of growth, (d) useful forms, (e) making pure and mixed cultures, (f) harmful forms and how they are scattered.
8. List seven enemies of the forest, and give a means of protection against each.
9. Name five adaptations for seed dispersal. Give an example of each.
10. State what biology teaches you in regard to any five (5) of the following: (a) value of clover, alfalfa, etc., as crops, (b) effect of plants on the atmosphere, (c) presence of bees in a garden, (d) reasons for cooking food, (e) advisability of vaccination, (f) coughing and sneezing in public places, (g) danger in the use of headache powders, (h) use of common drinking cup.

Chemistry

Write the number of this paper at the head of your answer paper.

Economy plus Extreme Utility —and Jewell Durability

This versatile electrical indicating instrument meets many needs in performing laboratory exercises in physics and electricity courses.

The double Pivot D'Arsonval movement has a center zero, with the scale divided into 50 divisions on either side. Full scale deflection, either side of center zero is secured with approximately 500 microamperes.

The protective features of this instrument eliminate almost all possibilities of damage from misuse. When connections are made to the binding posts, the circuit is not completed until button R_1 is pressed, which places a protective resistance in series with the coil of the instrument. Five hundred microamperes, or a terminal potential of 5 volts, is necessary for full scale deflection either side of zero. When button R_2 is depressed full scale deflection results at 500 microamperes or 100 millivolts. Maximum sensitivity is secured by depressing button O, with each small division equivalent to 20 microamperes.

The instrument is mounted in a slant-front metal case that places the scale at an easily read angle and protects the instrument from damage.

Your laboratory should have one of these instruments for each student experiment group.

Jewell Pattern 51
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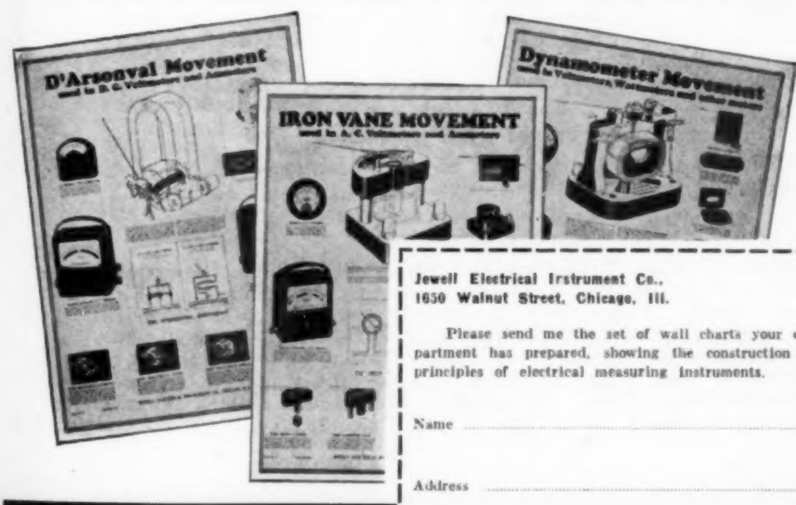
Secure these charts for class instruction



Jewell Electrical Instrument Co.,
1650 Walnut Street, Chicago, Ill.

Please send me the set of wall charts your educational department has prepared, showing the construction and operating principles of electrical measuring instruments.

Name ....

Address ....

Do not write on this answer paper. Number and letter each answer to correspond to the question. All "scratch work" should be on your answer paper.

Atomic weights: C=12, N=14, Na=23, Mg=24, S=32, Cl=35.5.

Questions 1, 2, 3, and 4 are required.

1. Answer the questions below for either Carbon Dioxide or Hydrogen Chloride: (a) How is it prepared and collected? (b) Make a labeled sketch of the apparatus. (c) Write the equation for the above reaction. (d) How does it occur in nature? (e) What are its properties, chemical and physical? (f) How would you test or identify it? (g) What are its uses?
2. List any five (excluding the one chosen in question 1) of the following gases vertically, and beside each put the letters corresponding to the properties given below: Carbon dioxide, chlorine, sulphur dioxide, nitrogen, hydrogen chloride, carbon monoxide, hydrogen, oxygen, ammonia, hydrogen sulphide.
   (a) Heavier than air (H);
   (b) Soluble in water (S. S.=slightly soluble, M. S.=moderately soluble, V. S.=very soluble);
   (c) Combustible (C);
   (d) Acid Anhydride (A);
   (e) Has an odor (O); has no odor (N. O.).
3. (a) Name three laws which the Atomic Theory explains. (b) State Avogadro's Hypothesis.
4. The action of a certain acid on sodium hydroxide formed 23.4g. of sodium chloride. (a) What acid was used? (b) Write the balanced equation for the reaction. (c) What weight of sodium hydroxide was needed?

Answer any two of questions 5, 6, 7, 8

5. What volume of ammonia gas, under standard conditions, would be formed by treating 10 grams of magnesium nitride with just enough water for the following reaction? $6H_2O$ & Mg_3N_2= $3Mg(OH)_2$ & $2NH_3$.
6. Distinguish by means of their essential properties or characteristics between (a) An ion and an atom; (b) An acid salt and a normal salt; (c) A strong and a weak base; (d) A compound and a mixture.
7. Give proofs that the following statements are true: (a) Carbon dioxide is an acid anhydride; (b) Air contains carbon dioxide; (c) Air is not a compound; (d) Sodium is a base forming element; (e) Calcium is an abundant element.
8. Name without repetition: (a) two metals which act with cold water; (b) two metals which when heated act with steam; (c) two metals which act with dilute sulphuni acid or dilute hydrochloric acid.
   In each part write *one* reaction typical of the action.

QUESTION AND ANSWER.

Q.—What is the most important nut on an automobile?
A.—The nut that holds the steering wheel.

BOOKS RECEIVED.

Examples in Plane Trigonometry by Winfield M. Sides, Department of Mathematics, Phillips Academy, Andover, Massachusetts. First Edition. Cloth. Pages xii+79. 12.5x19 cm. 1931. McGraw-Hill Book Company, 370 Seventh Avenue, New York, N. Y. Price 70 cents.

The Romance of Transport by Ellison Hawks, Fellow of the Royal Astronomical Society and Editor of The Meccano Magazine. Numerous Illustrations. Cloth. 333 pages. 14.5x21 cm. 1931. Thomas Y. Crowell Company, New York, N. Y. Price $3.00.

Tests in Chemistry by Charles E. Dull, Head of Science Department, West Side High School and Supervisor of Science for the Junior and Senior High Schools, Newark, New Jersey. Paper. 28 Tests. 19x24.5 cm. 1931. Henry Holt and Company, One Park Avenue, New York, N. Y.

A Test to Accompany A General Science Workbook by Charles H. Lake, Louis E. Welton, and James C. Adell. Form A with 16 units. Paper. 19.5x26 cm. 1931. Silver, Burdett and Company, New York, N. Y. Price $1.80 per set.

Meteorology by Donald S. Piston, Assistant Professor of Physics, University of Maine, Orono, Maine. Cloth. 94 Illustrations. Pages viii+187. 15x22 cm. 1931. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Pa. Price $2.50.

Animal Ecology by Royal N. Chapman, Dean of the Graduate School of Tropical Agriculture and Director of the Pineapple Experimental Station, University of Hawaii. First Edition. Cloth. Pages x+464. 14x23 cm. 1931. McGraw-Hill Book Company, 370 Seventh Avenue, New York, N. Y. Price $4.00.

Philisophy and Modern Science by Professor Harold T. Davis, Indiana University. Cloth. Pages xiv+335. 14.5x23 cm. 1931. The Principia Press, Bloomington, Indiana. Price $3.50.

Science Education in the Secondary Schools of Sweden by Holger Frederick Kilander, Professor of Biology and Hygiene, Upsala College, East Orange, New Jersey. Cloth. Pages vi+166. 14.5x23 cm. 1931. Bureau of Publications, Teachers College, Columbia University, New York City. Price $1.75.

PAMPHLETS RECEIVED.

Notes on Blow Pipe Analysis by Nicholas Knight, Professor of Chemistry, Cornell College, Mount Vernon, Iowa. Thirteenth Edition. 19 pages. 14x16 cm. 1932.

Physical Terminology by Duane Roller, Professor of Physics, University of Oklahoma, Norman, Oklahoma. Reprinted from The Scientific Monthly, December, 1930, Vol. XXXI. 5 pages. 17.5x25 cm.

Some Photoelectric Properties of Mercury Films by Duane Roller, W. H. Jordan and C. S. Woodward, Department of Physics, University of Oklahoma. Reprinted from Physical Review, Vol. 38, 1931. 5 pages. 18x25.5 cm.

Turtox Lantern Slides for Bacteriology, Botany, Embryology, Histology, Parasitology, Zoology and Related Sciences. Catalog No. 3. 67 pages. 21.5x28 cm. 1931. General Biological Supply House, 761-763 East Sixty-ninth Place, Chicago, Illinois.

Living Specimens for The Biology Laboratory. 39 pages. 15x22.5 cm. 1931. General Biological Supply House, 761-763 East 69th Place, Chicago, Illinois.

Turtox Teachers' Manual and Biology Catalog. 300 pages. 15x23 cm. 1930. General Biological Supply House, 761-763 East 69th Place, Chicago, Illinois.

Turtox Service Leaflet, Numbers 1 to 45 now ready. Each leaflet is two to four pages of practical helps for the teacher and student of biology; No. 1 How to make an insect collection, No. 10 The School Terrarium, No. 26 Making Biology Charts, etc. Sent on request. General Biological Supply House, 761-763 East 69th Place, Chicago, Illinois.

Turtox Biological Apparatus. Catalog No. 32. 227 pages. 21.5x28 cm. 1931. General Biological Supply House, 761-763 East 69th Place, Chicago, Illinois.

Biological Field Work including a Directory of Summer camps and Biological stations. 100 pages. 11x20.5 cm. 1931. General Biological Supply House, 761-763 East 69th Place, Chicago, Illinois.

BOOK REVIEWS.

Introductory College Chemistry by Harry N. Holmes, Professor of Chemistry in Oberlin College. Revised Edition. Pages viii+534. 15x21.5x3.5 cm. Many illustrations. Waterproof cloth. 1931. Macmillan Co.

This book was written for the student who enters college without high school chemistry. The usual sequence of chapters develops the fundamental principles in a very clear fashion, the chapters dealing with phases of physical chemistry are particularly well written. Numerous problems placed throughout the body of the chapters should aid the student in clinching the theory. Each chapter is followed by ample exercises and references to the literature for further reading. There is also a chapter outline which should help the student.

The electronic concept is introduced early in the text though it is not extensively used.

Subjects to which whole chapters are devoted, not found in the usual text, are "Nitrogen Fixation," "Photochemistry" and "Colloid Chemistry."

Illustrations are numerous and of excellent quality. This text should be given consideration by every teacher of beginning college chemistry. Druley Parker.

Smith's Introductory College Chemistry by James Kendall, Professor of Chemistry in the University of Edinburgh; formerly Professor of Chemistry at Columbia University and at New York University. First edition. Pages xii and 533 and appendix of 4 pages. 13.5-x20.5x4 cm. 15 full page illustrations. Cloth. The Century Co.

The Alexander Smith Texts have been favorites for many years in engineering and technical schools and the Kendall revisions of these texts have been widely adopted. This book is an attempt to meet the demands for a text which will give a thorough understanding of the fundamental principles of chemistry but at the same time meet the demands for a text suitable for the liberal arts colleges.

The major portion of the book deals with the fundamental principles of chemistry while some eighty pages are devoted to organic and biochemistry and its relation to daily life. The chemistry of the metals is confined to the last ninety pages.

On looking thru the book one gains the impression that it is a "cut-down" version of the more comprehensive text by the same author, as indeed it is.

Those schools which have been searching for a text with the good qualities of the former texts but at the same time less extensive will find this book worth examining.

It may be regretted by some that valency, oxidation and reduction are not treated from the electronic standpoint.

The illustrations are line drawings and photographs of excellent quality. Druley Parker.

Physical Science, An Introduction to the Specialized Courses in College Science by Herbert Brownell, Professor of the Technique of Instruction in Science, Teachers College, University of Nebraska. First Edition. Cloth. Pages xiv+313. 14.5x23. 1931. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $2.50.

In writing this book the author has set himself the problem of stimulating thought effort and developing a desire to know. A number of difficulties are met at once. The students have had a great range of experiences and a wide difference in previous science courses in the secondary school. These conditions demand careful selection of the vocabulary used. The field of physical science is so large that selection of subject matter that will most readily attain the primary

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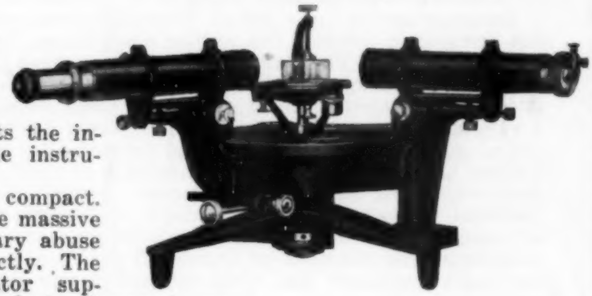

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aims and also give the most valuable fund of science information is a topic on which probably no two teachers will agree and there is little objective evidence on which to base conclusions.

Recognizing the loose use of scientific terms even by college people not trained in science, the author emphasizes the exact meaning of scientific words. The difficulty encountered here is very evident; e. g. in the first paragraph the author uses the word *energy* just as if it were completely understood by all, when in reality this word has a very definite meaning which is frequently confused with the meaning of work, power, or force. But notwithstanding this difficulty the author has in general used a carefully selected vocabulary and has fully explained new scientific terms as they are used. It is quite doubtful, however, if many students will grasp the full significance of many such terms as density, power, pressure, etc., by lecture and reading alone; solution of numerical problems and laboratory work are the experiences that clear up such terms in the minds of many students.

At the close of each chapter the author has prepared directions for review including the use of a check list of new terms, a summary of the chapter, questions, topics for special investigation and report, and reading references. The appendixes, eight in number, contain material as follows: I calls attention to the wonders of the modern world; II gives a chronological table of "notable events in aviation" of doubtful value in a book of this type; III lists some typical chemical equations showing the relation of acids, bases and salts, and gives other interesting chemical facts; IV is a series of brief sketches of scientists arranged in periods and sketches of inventors and inventions; V is a short book list; VI gives directions for some laboratory work and observation; VII is a two page discussion of teaching aims; VIII is a check list of scientific terms arranged by chapters as used in the text.

This book is an excellent outline of subject matter for the unified or survey course in physical science for college freshmen. It is well written and deserves the attention of all teachers and administrators planning such a course. G. W. W.

The Story of Science by David Dietz, Fellow of the Royal Astronomical Society; Member of the American Astronomical Society and the Societe Astronomique de France; Lecturer in General Science, Western Reserve University; Member, Ohio Academy of Science. Cloth. Illustrated. Pages xvii+387. 14.5x22 cm. 1931. Sears Publishing Company, Inc., 114 East 32nd Street, New York. Price $3.50.

Here is science presented by a master entertainer. The author, who is a scientist, teacher, popular lecturer, and science editor, knows how to make a technical topic clear to the layman or to the school boy or girl. This book is an accurate statement of the important facts and theories of astronomy, geology, physics, chemistry, and biology. The adult who has never had the advantages of high school science courses can read this book and get a fair knowledge of much that has been discovered in all the fields of science. Stars and nebulae, mountain building and the story of the rocks, atoms and electrons, waves and quanta, amoebae and men—not scraps of unrelated material but a story of development and growth. The reader will make the acquaintance of Barnard, Bequerel, Compton, Curie, Kepler, Koch, Mendel, Michelson, Riccioli, Rutherford, Versalius, Volta and a host of others whose discoveries have advanced civilization to its present place. Order two or three copies of the book; they will be kept busy. G. W. W.

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and of the Teaching of Science, University of Michigan, and Head of the Department of Science in the University High School. Cloth. Pages xx+424, 13x19.5 cm. 1931. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Pa. Price $3.00.

This book follows the same general plan used in the preceding volume by the same author, *A Digest of the Investigations in the Teaching of Science in the Elementary and Secondary Schools.* The investigations for this volume were published mainly from 1925 to 1930 but some of the abstracts are of unpublished Master's or Doctor's dissertations. In selecting the reports to be abstracted the author called upon the members of the National Association for Research in Science Teaching and received the active cooperation of nearly all the members. The selection, therefore, may be considered to be the combined choice of the group of judges most highly qualified to elect the most useful studies.

Eight abstracts are given in the teaching of science in the elementary school, eighteen in the teaching of general science in the secondary school, sixteen in the teaching of botany, eighteen in the teaching of physics, sixteen in chemistry, ten in miscellaneous investigations in the teaching of science in the secondary school, and seven in the teaching of science at the college level.

These digests give the essence of each article—concentrated reports for investigators, administrators and teachers There is great need for books of this type By use of these two books by Dr. Curtis no science teacher need be ignorant of the important studies that have been made in science teaching. G. W. W.

The Principles of Organic Chemistry by James F. Norris, Professor of Organic Chemistry, Massachusetts Institute of Technology. Third Edition. Cloth. Pages xii+595. 14x20.5 cm. 1931. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $3.00.

The Principles of Organic Chemistry is a book entirely worthy of its place in the International Chemical Series. It was originally written in 1912 by James F. Morris, Professor of Organic Chemistry in the Massachusetts Institute of Technology. The reviewer used the first edition of this book when he was Professor of Organic Chemistry in Carleton College, Minnesota in the school year 1920-1921, and found it satisfactory for class use. He used the same book the following school year with even greater success in class work in the College of William and Mary in Virginia. The second edition of the book which was released by the same author in 1922 has been used for many years past as a standard text in many colleges and universities scattered throughout the country. The writer used it very successfully two years ago in a class in organic chemistry in the Crane Evening College. The book has just undergone a second thorough revamping by its original author according to a very definite plan laid out in the preface to this third edition dated May 1931.

This book on the Principles of Organic Chemistry has three important features: It covers thoroughly every branch of elementary organic chemistry with the emphasis always on principles. It has a fine set of exercises and practical problems at the end of each chapter, which are quite simple at first and become increasingly difficult as the student advances through the text. It gives the instructor an excellent background for his lectures. He may use the lecture period to interpret this excellent book or he may lecture from notes taken from a variety of sources and require his students to use this book for supplemental and collateral reading to give the student of average ability a better understanding and a proper appreciation of the lecture work. A. F. McLeod.

Problems in the Teaching of Secondary-School Mathematics, by Ernest R. Breslich, Associate Professor of the Teaching of Mathematics, the University of Chicago. Pages vii+348. 23x16 cm. 1931. University of Chicago Press. Price $3.00.

This book is the second of a series in the teaching problems of secondary-school mathematics. The first book, entitled The Technique of Teaching Secondary-School Mathematics, deals with problems relating to general procedure; the second book deals with specific teaching problems. The following list of chapter headings indicates the scope of the discussion.

I Problems Relating to the Teaching of Mathematics in the Secondary Schools.

II Problems Relating to Arithmetic in Secondary-School Mathematics.

III The Teaching of Mathematics in the Secondary School.

IV Developing Understanding of the Fundamental Concepts of Mathematics.

V How to begin the Study of Algebra.

VI The Processes of Algebra.

VII Teaching how to solve Equations.

VIII Teaching Pupils how to solve Verbal Problems.

IX The Teaching of Formulas, Functions, and Graphs.

X The Teaching of Intuitive Geometry.

XI The Teaching of Demonstrative Geometry.

XII The Teaching of Three-dimensional Geometry.

XIII The teaching of Trigonometry and Logarithms.

Professor Breslich has searched the literature on the teaching problems of secondary mathematics—Arithmetic Algebra, Intuitive Geometry, Demonstrative Geometry, both Plane and Solid—listed these problems and discussed the various proposed solutions. At the end of each chapter we find an extensive bibliography covering the topic under discussion. The book should be in the hands of every teacher of secondary mathematics and every student who is preparing to teach secondary mathematics. J. M. Kinney.

Intermediate Calculus, by Percy F. Smith, Ph. D. and William Raymond Longley, Ph. D., Professors of Mathematics at Yale University. Pages xiii+457. 15x21 cm. 1931. Ginn and Company, Boston $3.00.

In recent years many tests have been written to meet the growing demand for the introduction of calculus in the first college year. Among these is one written by Longley and Wilson entitled "Introduction to the Calculus." The Intermediate Calculus is designed more especially to follow the latter. However, it may follow any text which has laid a good foundation in the differential and integral calculus of the algebraic functions.

There are in all nineteen chapters. The first four chapters are devoted to review material. They include a collection of formulas from elementary mathematics and a review of analytic geometry, differential and integral calculus (algebraic functions) In the fifth chapter we find a treatment of the exponential and logarithmic functions. The trigonometric functions follow in the sixth chapter. Among the remaining chapters we find the following to be of special interest: Solution of Equations, Empirical Equations, Polar Coördinates, and Applications, Parametric Equations, and Solid Analytic Geometry. J. M. Kinney.

Methods in Educational Research, by Frederick Lamson Whitney, Director of Educational Research Colorado State Teachers College, Greeley, Colorado. Pages vii+536. 1931. D. Appleton and Company, New York.

The growth of research in education has made the need for

manuals and text-books on the technique of research increasingly apparent. This book by Professor Whitney is designed to meet the requirements of a course in the scientific techniques of social study as applied to the particular field of education. It is written for the guidance of graduate students in institutions of research, such as are found in modern universities and teachers colleges. The methods presented in the book are the results of seven years experience in directing the work of graduate students.

In outline the book gives, (1) a summary of the underlying motives and philosophy of research, (2) methods of selecting a problem and planning its presentation, (3) a classification of the types of research methods to be used, (4) directions on the analysis and classification of data, (5) rules and directions for guidance in writing the final report of research, (6) an analysis of the traits and abilities required for success in research, and (7) an annotated and a general bibliography on scientific method and type studies representative of the application of the scientific method to modern research.

The authors classification of the methods of research as; experimentation, the survey, historical research, prognostic research, and philosophical analysis, is more a subjective system of classifying thesis problems than it is an analysis of present day research methods, for it is apparent that many institutions would not include philosophical analysis in the methods of research. In Chapter V of the book there is an excellent and very complete list of bibliographical sources. As a text-book in an introductory research course or seminar this book can be recommended to give the student an outline of the general problem research. J. M. O'Rourke.

Teaching the Elementary Curriculum, by Sheldon Emmor Davis, President of State Normal College, Dillon, Montana. Pages ix+550. 1931. The Macmillan Company, New York.

Books on teaching methods are not unknown or unusual, but it is always interesting to read a reformulation or synopsis of what is being done. This book by Dr. Davis does just that. It briefly and cogently outlines modern objectives and methods of realizing the objectives of the curriculum in the elementary school.

In scope the book covers the whole field of the elementary school curriculum, having chapters on reading, spelling, handwriting, language and composition, music, fine arts, manual arts, health, science, arithmetic, geography, history, civic and character education, and the school library. There is also a general bibliography on methods and curriculum, and a glossary of educational terms. Since the field covered by the book is so extensive, the chapters are short and give a summary discussion of the field of each subject. The method of treatment in each chapter is to discuss the objectives, motives, teaching procedures and testing programs for the particular subject matter in question. One notable feature in the supplementary material at the end of each chapter is the author's brief recollections of the methods and subject matter used when he was in school. This material shows an interesting contrast to the modern viewpoints expressed in the body of the chapter.

The value of this book will be in its adaptability to introductory courses in elementary education. J. M. O'Rourke.

Introduction to the Use of Standard Tests, by Sidney L. Pressy, Professor of Psychology, Ohio State University, and Luella Cole Pressy, Assistant Professor of Psychology, Ohio State University. Pages vi+266. 1931. World Book Company, New York.

This book is a revision of the authors' earlier edition, made necessary by the rapid growth and change in standard tests since 1922. It is an introductory text covering the whole testing program in a

non-technical way. The compact yet clear cut exposition of the topic makes the text a valuable handbook to teachers, supervisors, and superintendents who are not already familiar with the field.

The first chapters are devoted to a discussion of the nature of tests, the types of problems which may be dealt with profitably by means of tests, methods of handling results, and a few cautions concerning the misuse of tests. Then, tests in the various school subjects, both elementary and high school, are taken up one at a time. Possible uses of the tests in the various fields together with the authors' evaluation of the tests in general for that particular subject are given. A few of the most widely used tests in each field are mentioned and used as illustrative material. Tests of mental ability are discussed in much the same way, with emphasis on the particular uses of test results. Finally, certain general principles relating to the whole testing program, such as organization and planning of the testing program and relating the work to practical problems, are emphasized. G. E. Hawkins.

Shop Mathematics, Part I Shop Arithmetic, prepared by the Extension Division of the University of Wisconsin, by Earle B. Norris, Dean of Engineering, Virginia Polytechnic Institute, formerly Professor of Mechanical Engineering at the University of Wisconsin, and Kenneth G. Smith, State Supervisor of Vocational Industrial Education, Michigan, formerly Associate Professor of Mechanical Engineering at the University of Wisconsin. Third edition. Pages xv+271. 1931. McGraw-Hill Book Company, New York. Price $2.00.

This volume on shop arithmetic is an outgrowth of the instruction papers used in Shop Mechanics as developed by the extension division of the University of Wisconsin. The book is suitable for extension work or for classroom use in industrial or trade schools.

The first twelve chapters are devoted to instruction in arithmetic. The meaning of such terms as fraction, percentage, and ratio and proportion are explained in detail. The topics covered include the fundamental operations with common and decimal fractions, square roots, and areas and volumes of simple figures. Thus the mathematics is practically the same as that taught in the elementary schools, but the book is written in the language of the adult and the problems are chosen almost entirely from the shop. Chapters thirteen to eighteen furnish further practice, develop the ability to handle simple formulas, and especially serve to impart a knowledge of the principles of mechanics. A chapter on Logarithms and one on the Slide Rule are included for the benefit of those students who plan to continue with studies in industrial or engineering courses.

The text contains an ample number of exercises, some of which furnish drill in the mechanics of arithmetic, and others which require application of the processes to concrete situations. This book should serve a real need in classes requiring this type of material.

G. E. Hawkins.

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The rainbow colors of a pheasant's feathers are rainbow colors in fact, to a very considerable extent. That is, the hues are largely due to reflection from transparent substances in the feather, just as the rainbow is due to reflected light from transparent raindrops.

This does not mean that feathers have no colors of their own. There are plenty of pigment bodies in parts of the feathers, supplying a sort of ground-color; but the real "show" of a beautiful bird's plumage is mostly a matter or reflected light.

"CURE-ALLS" CURE NONE.

Disaster usually overtakes tuberculosis patients who forsake the recognized method of treatment afforded by rest, fresh air and nourishing food to follow "discoveries." There are many announcements of so-called cures each year. They gather a large toll of lives among those who abandon the well-tried regimen of approved care. Hope dies slowly, and most people believe there is a quick cure for every ailment if one could only find it. Reputable physicians know of no such drug for tuberculosis. But often those who try such remedies think they notice a sudden improvement, for the progress of the disease is marked by variations—"ups and downs." A feeling of temporary optimism is created which may lead to the abandonment of the long period of rest prescribed by the physician.

The last 20 years has seen 721 "cures" for tuberculosis come and go. There may have been more than this number, for the figure stated refers to those which have been exploited sufficiently to find a place in the files of the National Tuberculosis Association, which sponsors the Christmas seal sale, and conducts the all-year-round campaign against the disease. The primary interest of this organization would be to give sanction to such a cure if it were developed, but it also seeks to protect sick people from imposition by quacks, as well as from being harmed by innocent persons who are carried away by the enthusiasm of temporary success.

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An imaginary or complex mathematical curve, Prof. Kasner said, has a peculiarity that a piece of it can never be made like a straight line no matter how short a piece is taken Prof. Kasner studied the ratio between the length of a straight line cutting such a curve when the length of the piece cut off is made smaller and smaller, and found some curious things.

In ordinary curves this ratio is one but in the special cases considered by him the ratio can have only discontinuous values less than one, such as 0.94, 0.86, 0.80, etc. These values become realized when electrons are assumed to shoot out with the velocity of light and measurements are made in the space of Minkowski and Einstein.

Jerkiness of this kind reminds one of the things observed in the quantum theory. Prof. Kasner suggested that there may be some relation between the mathematical fact and the physical quantum laws.—*Science Service.*

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These magnets possess a far greater magnetic and repelling force than magnets made from Tungsten steel. The cobalt-steel alloy invented by Prof. K. Honda of Tokio University has 3.5 times the magnetic retentivity. These magnets therefore add new force and create new interest in experiments in which they are used. More iron filings can be held; a longer series of tacks, brads, steel balls, etc.

In addition they make possible many strikingly new demonstrations. The repelling force of like poles is forcefully demonstrated by releasing two cylindrical magnets which have been held side by side on a smooth surface with their like poles adjacent. They will roll 50 to 60 cm. apart.

Many other experiments in magnetism heretofore demonstrated under difficulty in the laboratory are made vividly convincing through the use of these powerful magnets. The cylindrical magnets are made in three sizes; *small* for individual student's use; *No. 10MA, Length, 5 cm.; Dia. 6.5 mm.;* Per pair **$0.35**; *medium* for teachers' and advanced students' use; *No. 10MB, Length, 12.5 cm.; Dia. 10 mm.;* Per pair **$1.35**; *large* for lecture purposes; *No. 10MC, Length, 18 cm.; Dia. 14 mm.;* Per pair **$5.00**.

The U-Magnets are made in 2 sizes; *small* for work in which small horseshoe magnets are ordinarily employed; *No. 184MA—Length 7.5 cm.*—**$0.75** each; *large* for work ordinarily suited to larger U-Magnets; *No. 184MB—Length 12.5 cm.*—**$1.75** each.

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